FINAL

Intrinsic Remediation Corrective Action Study Addendum for POL Bulk Fuel Storage

Myrtle Beach Air Force
Myrtle Beach, South Carolina

Prepared For

Air Force Center for Environmental Excellence
Technology Transfer Division
Brooks Air Force Base, Texas
San Antonio, Texas

and

Air Force Conversion Agency (AFBCA/SEP)
Myrtle Beach Air Force
Myrtle Beach, South Carolina

September 1999

PARSONS

Parsons Engineering Science, Inc. • A Unit of Parsons Infrastructure & Technology Group Inc.
1700 Broadway, Suite 900 • Denver, Colorado 80290 • (303) 831-8100 • Fax: (303) 831-8208 • www.parsons.com

07 September 1999

Mr. Jerry Hansen
Technical Program Manager
AFCEE/ERT
3207 North Road, Bldg. 532
Brooks AFB, TX 78235-5363

Subject: Submittal of the Final Intrinsic Remediation Corrective Action Study Addendum for POL Bulk Fuel Storage Area, Myrtle Beach AFB, South Carolina (Contract F41624-92-D-8036-0025)

Dear Mr. Hansen:

Enclosed please find two copies of the September 1999 Final Intrinsic Remediation Corrective Action Study Addendum for POL Bulk Fuel Storage Area, Myrtle Beach AFB, South Carolina. This report was prepared by Parsons Engineering Science, Inc. (Parsons ES) for the Air Force Center for Environmental Excellence Technology Transfer Division (AFCEE/ERT) and the Air Force Base Conversion Agency (AFBCA/SEP), Myrtle Beach AFB, South Carolina.

The intent of the CAS Addendum was to determine the role of natural attenuation in remediating fuel contamination in groundwater at the POL Bulk Fuel Storage Area. The draft CAS Addendum was submitted to AFCEE in June 1999. Comments on the draft CAS Addendum were received from AFCEE as reviewed by Jon Atkinson (dated 22 July 1999). Responses to these comments were prepared by Parsons ES and are attached to this letter.

If you have any questions or require additional information, please call me at (303) 831-8100.

Sincerely,

PARSONS ENGINEERING SCIENCE, INC.

Bruce M. Henry

Bruce M. Henry, P.G.
Project Manager

Enclosures
c.c. Mr. Robert Courtwright – Myrtle Beach AFB (two copies)
Mr. Don Kampbell – USEPA NRMRL (two copies)

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Responses to AFCEE Comments on the Draft Intrinsic Remediation Corrective Action Study Addendum for POL Bulk Fuel Storage Area, Myrtle Beach AFB, South Carolina: 22 July 1999

Comment 1) Page 5, Sec 1.2, Para 2, Last Sent: The location of the cited ditch should be briefly described. If it is the ditch described in the preceding sentence, this fact should be stated.

Parsons ES Response: *The text will be changed to indicate that the cited ditch is the same ditch that parallels Phyliss Drive in the preceding sentence.*

Comment 2) Page 6, Table 1: Under the column heading "Analyte," a typo occurs in "Bicarbonate."

Parsons ES Response: *The table will be corrected an indicated.*

Comment 3) Page 13, Sec 2.2, Para 2, Sent 2 and Page 14, Table 3: Here, and throughout the report, recommend that all analytical results be reported to no more than three significant figures (e.g., 15.8 μg/L) to better reflect accuracy and precision of these results.

Parsons ES Response: *All reported analytical results will be changed to three significant figures as indicated.*

Comment 4) Page 13, Sec 2.2, Para 2, Last Sent: Suggest stating whether contaminant transport modeling for the initial study predicted this increase in BTEX concentrations in the downgradient portion of the plume.

Parsons ES Response: *The increase in concentrations in the downgradient portion of the plume (i.e., monitoring points MP-34S and MP-34D) is not consistent with model predictions. This difference can be accounted for by the amount of BTEX mass that was expected to discharge into the drainage ditch that parallels Phyliss Drive. Modeled discharge of BTEX mass to the ditch appears to be greater than the observed conditions. Some BTEX mass is apparently migrating beneath the ditch and Phyliss drive in the vicinity of monitoring points MP-34S and MP-34D. The text will be changed in Section 2.2, Paragraph 3 to reflect this observation.*

Responses to AFCEE Comments (continued)

Comment 5) Page 13, Sec 2.2, Para 3, Line 4: The typo "p10" needs to be corrected.

Parsons ES Response: *The correction will be made.*

Comment 6) Pages 22 and 23, Figs 4 and 5: Recommend placing the traces for these cross sections on a map.

Parsons ES Response: *The location of these cross sections will be shown on a new figure and inserted into the report.*

Comment 7) Page 24, Fig 6: Two points over a four-year period are barely adequate to depict temporal trends in BTEX concentrations on a line graph. Suggest using a bar graph or table to display these data.

Parsons ES Response: *Figure 6 will be deleted from the report and data cited for temporal trends in groundwater BTEX concentrations will be referenced to Table 3 and Figures 4 and 5.*

Comment 8) Page 25, Sec 2.2, Para 2, Last Sent: This sentence is erroneous; notable migration of the plume has occurred. Figure 7 depicts the plume toe, as defined by the 10 μg/L benzene contour, to have moved about 100 feet across Phyliss Drive. Additionally, Figure 3 depicts similar plume movement for total BTEX. Consequently, this sentence should be revised accordingly.

Parsons ES Response: *Because the BTEX plume has migrated across Phyliss drive in the vicinity of monitoring point pair MP-34S and MP-34D, comparison of observed migration to potential migration is not a reliable indicator of biodegradation. Therefore, the cited paragraph will be deleted.*

Comment 9) Page 29, Fig 9: Two points over a four-year period are barely adequate to depict temporal trends in BTEX concentrations on a line graph. Suggest using a bar graph or table to display these data.

Parsons ES Response: *Figure 9 will be deleted from the report and data cited for temporal trends in groundwater benzene concentrations will be referenced to Table 3. The text will be expanded to describe the increase in benzene concentrations observed in deep wells/points.*

Responses to AFCEE Comments (continued)

Comment 10) Page 48, Sec 3.0, Para 1, Sent 2: This sentence is erroneous; notable migration of the plume has occurred. Figure 7 depicts the plume toe, as defined by the 10 µg/L benzene contour, to have moved about 100 feet across Phyliss Drive. Consequently, this sentence should be revised accordingly.

Parsons ES Response: *Parsons ES concurs. Section 3.0, Paragraph 1, Sentence 2 will be deleted from the text. The following sentence will be added to Section 3.0, Paragraph 1: "Therefore, the toe of the BTEX plume has migrated beneath the southern ditch and Phyliss Drive in the vicinity of monitoring point pair MP-34S and MP-34D."*

Comment 11) Page 49, Sec 3.0, Para 3, Sent 1: This sentence is erroneous; notable migration of the plume has occurred as noted in comments 8 and 10. Consequently, this sentence should be revised accordingly.

Parsons ES Response: *Parsons ES concurs. Section 3.0, Paragraph 3, Sentence 1 will be deleted from the text.*

FINAL

INTRINSIC REMEDIATION

CORRECTIVE ACTION STUDY ADDENDUM

for

POL BULK FUEL STORAGE AREA
MYRTLE BEACH AIR FORCE BASE
MYRTLE BEACH, SOUTH CAROLINA

September 1999

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
BROOKS AIR FORCE BASE
SAN ANTONIO, TEXAS

and

AIR FORCE BASE CONVERSION AGENCY (AFBCA/SEP)
MYRTLE BEACH AIR FORCE BASE
MYRTLE BEACH, SOUTH CAROLINA

Prepared by:

Parsons Engineering Science, Inc.
1700 Broadway, Suite 900
Denver, Colorado 80290

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LIST OF ACRONYMS AND ABBREVIATIONS

$\mu g/L$	micrograms per liter
$\mu mhos/cm$	micromhos per centimeter
^{o}C	degrees Celsius
AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
AST	aboveground storage tank
BTEX	benzene, toluene, ethylbenzene, and xylenes
btoc	below top of casing
$CaCO_3$	calcium carbonate
CAS	Corrective Action Study
CO_2	carbon dioxide
CO_3^{2-}	carbonate
DO	dissolved oxygen
ES	Engineering Science, Inc. (now known as Parsons Engineering Science, Inc.)
Fe^{2+}	ferrous iron
ft/day	feet per day
ft/ft	foot per foot
ft/yr	feet per year
HCO_3^-	bicarbonate
IRP	Installation Restoration Program
LNAPL	light non-aqueous phase liquid
LTM	long-term monitoring
mg/L	milligrams per liter
msl	mean sea level
MTBE	methyl tert-butyl ether
mV	millivolts
NRMRL	National Risk Management Research Laboratory
ORP	oxidation-reduction potential
Parsons ES	Parsons Engineering Science, Inc.
POL	petroleum, oil, and lubricant
redox	oxidation-reduction
su	standard units
TEMBs	tetramethlybenzenes
TMBs	trimethylbenzenes
TOC	total organic carbon
USEPA	US Environmental Protection Agency
USGS	United States Geological Survey
UST	underground storage tank
VOCs	volatile organic compounds

1.0 INTRODUCTION

This Corrective Action Study (CAS) addendum was prepared for the Air Force Center for Environmental Excellence (AFCEE) by Parsons Engineering Science, Inc. (Parsons ES) as an update to the Final CAS (Parsons ES, 1997) previously conducted to evaluate intrinsic remediation for Installation Restoration Program (IRP) Site SS-03, the Petroleum, Oil, and Lubricant (POL) Bulk Storage Area, at the former Myrtle Beach Air Force Base (AFB) in Myrtle Beach, South Carolina. The first CAS sampling event was conducted in January 1995 to evaluate the use of intrinsic remediation for remediation of groundwater contaminated by petroleum hydrocarbons. This addendum summarizes the results of a second sampling event conducted as part of the evaluation of intrinsic remediation at the site. Results and predictions presented in the Final CAS (Parsons ES, 1997, hereafter referred to as the "Final CAS") are used as the basis for comparison.

In the Final CAS, comparison of benzene, toluene, ethylbenzene, and xylenes (BTEX); electron acceptor; and biodegradation byproduct isopleth maps for the POL indicated strong qualitative evidence of biodegradation of BTEX compounds. Geochemical data strongly suggested that biodegradation of fuel hydrocarbons was occurring at the site via the anaerobic processes of iron reduction, sulfate reduction, and methanogenesis. Patterns observed in the distribution of fuel hydrocarbons, electron acceptors, and biodegradation byproducts further indicated that biodegradation was reducing dissolved BTEX concentrations in site groundwater.

While the results of the Final CAS indicated that intrinsic remediation of BTEX compounds was occurring at the POL, it was suggested that without engineered source reduction, intrinsic remediation alone might not be sufficient to ensure protection of human health and the environment. This was due to a plume of mobile and residual light nonaqueous-phase liquid (LNAPL) present in the subsurface, and due to the proximity of a ditch along Phyliss Drive which was determined to be an exposure-point for groundwater contaminants discharging to surface water.

Therefore, the Air Force recommended that an engineered source removal, such as bioslurping, be implemented in conjunction with intrinsic remediation, long-term monitoring (LTM), and institutional controls. In the Fall of 1997, Battelle conducted a bioslurping pilot test. Results of the pilot test indicated that bioslurping would not be an effective alternative to remediate free and residual product at the site, primarily due to seasonal fluctuations in groundwater elevation and free product thickness. Natural attenuation is currently the only process acting to reduce source and dissolved contaminant mass at the site.

1.1 Scope and Objectives

The primary objective of this addendum is to evaluate changes in concentrations of dissolved BTEX, BTEX plume extent, and natural attenuation mechanisms that reduce BTEX mass and concentration between April 1994 and February 1999. Data collected in January 1995 for the Final CAS are used as a baseline for comparison. In February 1999 groundwater samples were collected from 28 existing monitoring wells by

researchers from the United States Environmental Protection Agency (USEPA) National Risk Management Research Laboratory (NRMRL) Subsurface Protection and Remediation Division. Data from an April 1994 sampling event also was added to this update to evaluate temporal trends of subsurface contaminants.

1.2 Site Background

The former Myrtle Beach AFB is located in Horry County, South Carolina, along the Atlantic coast. The former base occupies an area of approximately 3,793 acres on a strip of land known as the Grand Strand and is bordered by the city of Myrtle Beach to the east and south, the Intracoastal Waterway to the north, and wetlands/timberland/undeveloped land to the west [Engineering-Science, Inc. (ES), 1981; US Geological Survey (USGS), 1994]. The runways and the eastern side of the base were converted to use as the Myrtle Beach Municipal Jetport in 1993.

The POL is located in the northwestern quadrant of the base, west of Third Street and north of Phyliss Drive (Figure 1). A westerly flowing drainage ditch parallels the north side of Phyliss Drive. The POL was used to supply JP-4 fuel to aircraft on the flightline via tanker trucks.

Fuels have not been stored at the POL since base closure in 1993; however, many components of the former storage and distribution systems remain in place (Figure 1). The former fuel transfer area of the POL consists of a divided road running the length of the northwestern site boundary. Underground fuel transfer lines connect fuel storage areas that occupy most of the POL southeast of the fueling road to a pumphouse located in the fueling road median. Additional fuel transfer lines carried fuel along the median to individual fueling stations. The most conspicuous remnants of the POL are two steel aboveground storage tanks (ASTs) with capacities of 420,000 gallons and 1,050,000 gallons (Figure 1). Both ASTs previously were used to store JP-4 jet fuel. Each AST is surrounded by a secondary containment earthen berm, with drains from each of the bermed areas leading to an oil/water separator located south of the 420,000-gallon AST. Tanks and fuel lines were drained, but otherwise left intact, prior to base closure in March 1993.

Two underground storage tanks (USTs) and one AST also were formerly used to store fuel at the site (Figure 1). Two 25,000-gallon USTs were located south of the fueling road and east of the 1,050,000-gallon AST. The USTs previously stored gasoline and were removed after base closure in 1993. A 50,000-gallon AST, removed prior to a Phase I records search in 1981, was located east of the 1,050,000-gallon AST and south of the USTs (ES, 1981). The location of the former AST and USTs currently is overlain by a level earthen mound raised approximately 4 feet above the surrounding land surface.

A 10,000-gallon jet fuel spill occurred at the POL between the 1,050,000-gallon AST and the former 50,000-gallon AST. The exact date of the spill is unknown, but has been reported to have occurred between 1963 and 1967.

The POL has been included in several base investigations since its identification in the IRP Phase I Records Search (Parsons ES, 1997). Free product has been identified

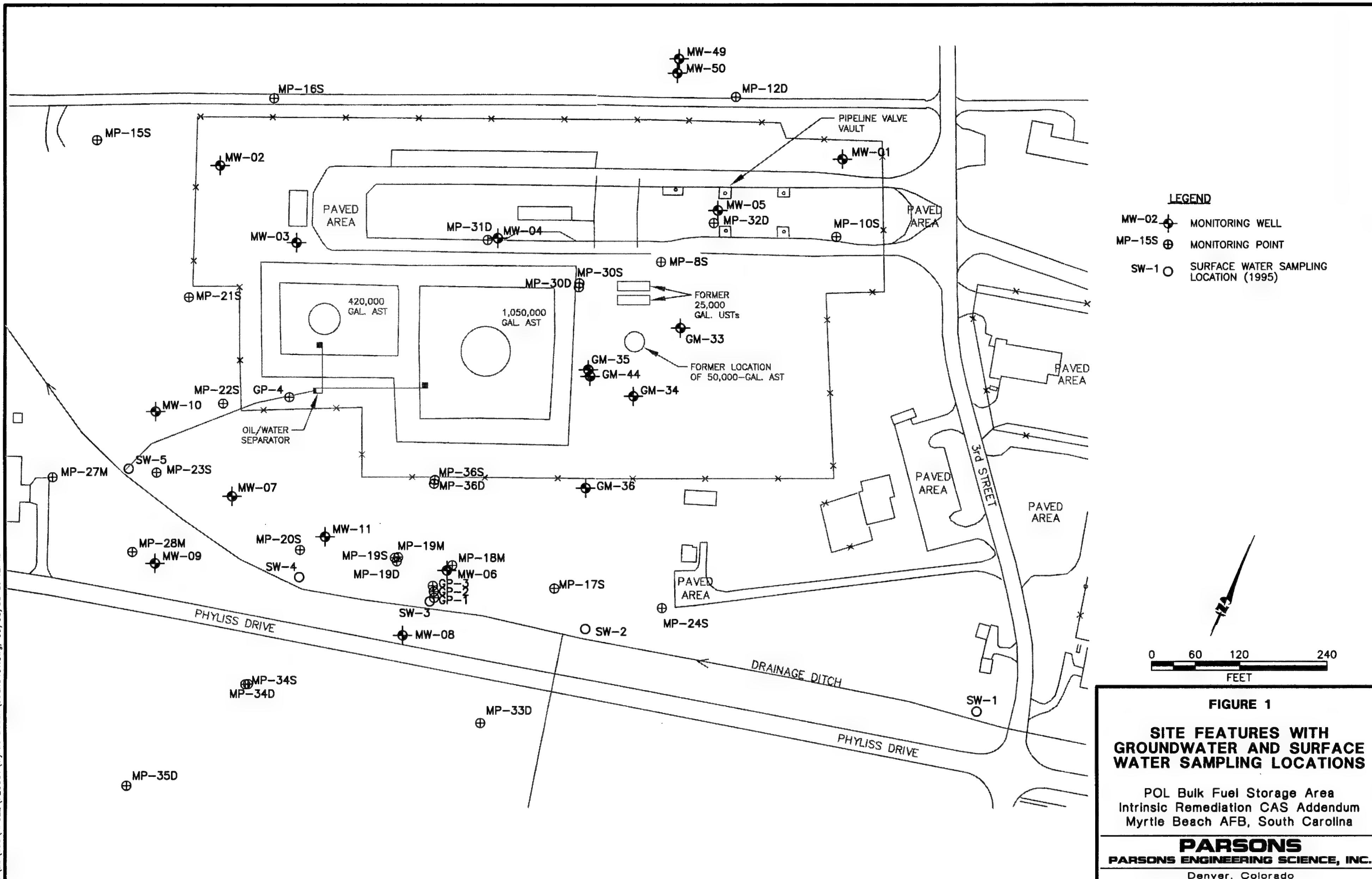

FIGURE 1

SITE FEATURES WITH GROUNDWATER AND SURFACE WATER SAMPLING LOCATIONS

POL Bulk Fuel Storage Area
Intrinsic Remediation CAS Addendum
Myrtle Beach AFB, South Carolina

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Denver, Colorado

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in two monitoring wells (MW-04 and MW-05) installed in the median of the fueling road, and in a below-grade pipeline valve vault (Figure 1). A soil gas investigation identified highly elevated concentrations of total volatile organic compounds (VOCs) north and south of the 420,000-gallon AST, and along a narrow corridor between the ditch paralleling Phyliss Drive. Petroleum hydrocarbons also have been observed in groundwater seeping into the ditch paralleling Phyliss Drive, approximately 500 feet hydraulically downgradient from the site.

2.0 MONITORING RESULTS

In February 1999, researchers from the USEPA NRMRL collected groundwater samples from 28 monitoring wells at the former Myrtle Beach AFB POL Yard. Groundwater samples were analyzed in the field for dissolved oxygen (DO), temperature, pH, conductivity, oxidation-reduction (redox) potential (ORP), alkalinity, carbon dioxide (CO_2), sulfide, and ferrous iron (Fe^{2+}). Additional sample volume was analyzed at the USEPA NRMRL in Ada, Oklahoma for BTEX, trimethylbenzenes (TMBs), methyl tert-butyl ether (MTBE), methane, ethane, ethene, nitrate + nitrite, ammonia, chlorides, total organic carbon (TOC), and sulfate. Analytical methods used are summarized in Table 1. Prior to purging and sampling each well, groundwater levels were measured to the nearest 0.1 foot.

2.1 Flow Direction and Gradient

Depth to groundwater was measured in all but one of the sampled wells in February 1999. Table 2 includes groundwater elevations for April 1994, January 1995, and February 1999. Contour maps of shallow groundwater elevations for January 1995 and February 1999 are presented on Figure 2. Because some wells are clustered and screened in deeper aquifer intervals, only wells reflecting the shallowest groundwater elevation were used to construct contour intervals on Figure 2. The predominant direction of shallow groundwater flow at the former Myrtle Beach AFB POL is to the south/southwest toward the drainage ditch north of, and parallel to, Phyliss Drive. Groundwater flow at the site is complicated by discharge to drainage ditches and the presence of groundwater divides, which vary with climatic conditions (precipitation).

Of the 27 wells at which groundwater elevations were measured in both January 1995 and February 1999, the water elevation decreased in 23 wells and increased in 4 wells from 1995 to 1999. Decreases in water elevations ranged from 0.01 foot (MP-18M) to 4.11 feet (MP-30S). Changes in groundwater elevation may be attributed to seasonal or annual variations in recharge (precipitation). In particular, water levels measured on January 18, 1995, followed a period of over 10 inches of rain since the beginning of the month (Parsons ES, 1997).

The average hydraulic gradient from the fueling road median (i.e., the contaminant source area near wells MW-04 and MW-05) to the drainage ditch (near MW-06) was 0.01 foot per foot (ft/ft) in January 1995. In February 1996 the average gradient along the same flow path was approximately 0.006 ft/ft. The drop in water table elevation near MP-30S (4.11 feet) reflects a flattening of the water table, or decrease in hydraulic gradient, from the fueling road median to the south drainage ditch.

TABLE 1
SUMMARY OF GROUNDWATER ANALYTICAL METHODS
FEBRUARY 1999
POL BULK FUEL STORAGE AREA
INTRINSIC REMEDIATION CAS ADDENDUM
MYRTLE BEACH AFB, SOUTH CAROLINA

Analyte	Method	Field (F) or Fixed-Base Laboratory (L)
Oxidation\Reduction Potential	Direct Reading Meter	F
Dissolved Oxygen	Direct Reading Meter	F
Conductivity	Direct Reading Meter	F
Temperature	Direct Reading Meter	F
pH	Direct Reading Meter	F
Ferrous Iron (Fe^{2+})	Colorimetric, Hach Method 8146 or equivalent	F
Sulfide	Colorimetric, Hach Method 8131 or equivalent	
Carbon Dioxide	Titrimetric, Hach Method 1436-01 or equivalent	F
Alkalinity (Carbonate [CO_3^{2-}] and Bicarbonate [HCO_3^-])	Titrimetric, Hach Method 8221 or equivalent	F
Nitrate + Nitrite	Lachat FIA Method 10-107-04-2-A	L
Ammonia	Lachat FIA Method 10-107-06-1-A	L
Chlorides	Waters Capillary Electrophoresis Method N-601	L
Sulfate	Waters Capillary Electrophoresis Method N-601	L
Methane, Ethane and Ethene	RSKSOP-175[a/] and RSKSOP-194	L
BTEX, TMBs, and MTBE	RSKSOP-122	L
TOC	RSKSOP-102	L

[a/] RSKSOP = Robert S. Kerr Laboratory (now known as NRMRL) standard operating procedure.

TABLE 2
SUMMARY OF GROUNDWATER ELEVATION DATA
POL BULK FUEL STORAGE AREA
INTRINSIC REMEDIATION CAS ADDENDUM
MYRTLE BEACH AFB, SOUTH CAROLINA

Sample Location	Sample Date	Datum Elevation (ft msl) [b/]	Depth to Water (ft btoc) [c/]	Depth to Product (ft btoc)	Product Thickness (feet)	Corr. Depth to Water [a/] (ft btoc)	Corr. GW Elevation (ft msl)
MW-01	Apr-94	25.13	5.32	- [d/]	-	5.32	19.81
	Jan-95	24.62	4.08	-	-	4.08	20.54
	Feb-99	24.62	4.70	-	-	4.70	19.92
MW-02	Apr-94	24.59	8.51	-	-	8.51	16.08
	Jan-95	24.04	5.21	-	-	5.21	18.83
	Feb-99	24.04	8.00	-	-	8.00	16.04
MW-03	Apr-94	24.97	7.88	-	-	7.88	17.09
	Jan-95	24.42	4.91	-	-	4.91	19.51
	Feb-99	24.42	7.10	-	-	7.10	17.32
MW-04	Apr-94	26.17	8.91	Product present		8.91	17.26
	Jan-95	25.64	8.02	6.27	1.75	6.71	18.93
	Feb-99	25.64	8.40	-	-	8.40	17.24
MW-05	Apr-94	24.09	5.80	Product present		5.80	18.29
	Jan-95	24.93	6.24	2.07	4.17	3.11	21.82
MW-06	Apr-94	25.52	11.89	-	-	11.89	13.63
	Jan-95	24.98	11.24	-	-	11.24	13.74
	Feb-99	24.98	10.70	-	-	10.70	14.28
MW-07	Apr-94	24.67	9.44	-	-	9.44	15.23
	Jan-95	23.86	6.36	-	-	6.36	17.50
	Feb-99	23.86	7.80	-	-	7.80	16.06
MW-08	Apr-94	23.69	9.48	-	-	9.48	14.21
	Jan-95	23.11	8.75	-	-	8.75	14.36
	Feb-99	23.11	8.20	-	-	8.20	14.91
MW-09	Apr-94	22.24	7.39	-	-	7.39	14.85
	Jan-95	21.70	5.99	-	-	5.99	15.71
	Feb-99	21.70	6.30	-	-	6.30	15.40

TABLE 2 (Continued)
SUMMARY OF GROUNDWATER ELEVATION DATA
POL BULK FUEL STORAGE AREA
INTRINSIC REMEDIATION CAS ADDENDUM
MYRTLE BEACH AFB, SOUTH CAROLINA

Sample Location	Sample Date	Datum Elevation (ft msl) [b/]	Depth to Water (ft btoc) [c/]	Depth to Product (ft btoc)	Product Thickness (feet)	Corr. Depth to Water [a/] (ft btoc)	Corr. GW Elevation (ft msl)
MW-10	Apr-94	23.25	8.75	-	-	8.75	14.50
	Jan-95	22.68	7.47	-	-	7.47	15.21
MW-11	Apr-94	26.05	11.65	-	-	11.65	14.40
	Jan-95	25.47	10.67	-	-	10.67	14.80
	Feb-99	25.47	10.70	-	-	10.70	14.77
MW-49	Jan-95	-	3.46	-	-	3.46	-
MW-50	Jan-95	-	2.58	-	-	2.58	-
GM-33	Apr-94	24.51	4.52	-	-	4.52	19.99
	Jan-95	23.97	2.50	-	-	2.50	21.47
GM-34	Apr-94	24.64	5.59	-	-	5.59	19.05
	Jan-95	24.11	3.35	-	-	3.35	20.76
GM-35	Apr-94	23.43	4.49	-	-	4.49	18.94
	Jan-95	22.90	2.37	-	-	2.37	20.53
GM-36	Apr-94	22.89	5.46	-	-	5.46	17.43
	Jan-95	22.31	2.42	-	-	2.42	19.89
GM-44	Jan-95	22.64	6.07	-	-	6.07	16.57
MP-8S	Jan-95	22.69	2.01	-	-	2.01	20.68
	Feb-99	22.69	4.60	-	-	4.60	18.09
MP-10S	Jan-95	23.00	1.50	-	-	1.50	21.50
	Feb-99	23.00	2.30	-	-	2.30	20.70
MP-12D	Jan-95	21.19	4.74	-	-	4.74	16.45
	Feb-99	21.19	5.70	-	-	5.70	15.49
MP-15S	Jan-95	20.70	3.64	-	-	3.64	17.06

TABLE 2 (Continued)
SUMMARY OF GROUNDWATER ELEVATION DATA
POL BULK FUEL STORAGE AREA
INTRINSIC REMEDIATION CAS ADDENDUM
MYRTLE BEACH AFB, SOUTH CAROLINA

Sample Location	Sample Date	Datum Elevation (ft msl) [b/]	Depth to Water (ft btoc) [c/]	Depth to Product (ft btoc)	Product Thickness (feet)	Corr. Depth to Water [a/] (ft btoc)	Corr. GW Elevation (ft msl)
MP-16S	Jan-95	20.97	3.26	-	-	3.26	17.71
	Feb-99	20.97	4.50	-	-	4.50	16.47
MP-17S	Jan-95	22.26	6.59	-	-	6.59	15.67
	Feb-99	22.26	7.10	-	-	7.10	15.16
MP-18M	Jan-95	22.79	8.19	-	-	8.19	14.60
	Feb-99	22.79	8.20	-	-	8.20	14.59
MP-19S	Jan-95	23.03	8.86	-	-	8.86	14.17
	Feb-99	23.03	8.70	-	-	8.70	14.33
MP-19M	Jan-95	22.99	8.01	-	-	8.01	14.98
	Feb-99	22.99	7.90	-	-	7.90	15.09
MP-19D	Jan-95	23.02	6.35	-	-	6.35	16.67
MP-20S	Jan-95	21.70	6.84	-	-	6.84	14.86
MP-21S	Jan-95	20.17	1.33	-	-	1.33	18.84
MP-22S	Jan-95	19.29	3.51	-	-	3.51	15.78
	Feb-99	19.29	4.30	-	-	4.30	14.99
MP-23S	Jan-95	16.90	1.67	-	-	1.67	15.23
MP-24S	Jan-95	21.80	5.85	-	-	5.85	15.95
MP-27M	Jan-95	19.90	4.58	-	-	4.58	15.32
MP-28M	Jan-95	19.70	4.19	-	-	4.19	15.51
MP-30S	Jan-95	22.24	2.49	-	-	2.49	19.75
	Feb-99	22.24	6.60	-	-	6.60	15.64
MP-30D	Jan-95	22.19	5.70	-	-	5.70	16.49
	Feb-99	22.19	6.70	-	-	6.70	15.49

TABLE 2 (Continued)
SUMMARY OF GROUNDWATER ELEVATION DATA
POL BULK FUEL STORAGE AREA
INTRINSIC REMEDIATION CAS ADDENDUM
MYRTLE BEACH AFB, SOUTH CAROLINA

Sample Location	Sample Date	Datum Elevation (ft msl) [b/]	Depth to Water (ft btoc) [c/]	Depth to Product (ft btoc)	Product Thickness (feet)	Corr. Depth to Water [a/] (ft btoc)	Corr. GW Elevation (ft msl)
MP-31D	Jan-95	23.23	6.77	-	-	6.77	16.46
	Feb-99	23.23	7.60	-	-	7.60	15.63
MP-32D	Jan-95	21.83	5.36	-	-	5.36	16.47
	Feb-99	21.83	6.20	-	-	6.20	15.63
MP-33D	Jan-95	20.39	3.73	-	-	3.73	16.66
MP-34S	Jan-95	18.95	3.03	-	-	3.03	15.92
	Feb-99	18.95	3.50	-	-	3.50	15.45
MP-34D	Jan-95	18.91	2.99	-	-	2.99	15.92
	Feb-99	18.91	3.50	-	-	3.50	15.41
MP-35D	Jan-95	20.26	3.55	-	-	3.55	16.71
	Feb-99	20.26	4.40	-	-	4.40	15.86
MP-36S	Jan-95	20.79	2.69	-	-	2.69	18.10
	Feb-99	20.79	4.80	-	-	4.80	15.99
MP-36D	Jan-95	20.78	4.11	-	-	4.11	16.67
	Feb-99	20.78	5.10	-	-	5.10	15.68

[a/] Corrected Depth to Water = Measured Depth to Water - (0.75 x Product Thickness).

[b/] ft msl = Feet above mean sea level.

[c/] ft btoc = Feet below top of casing.

[d/] No product present or product thickness not quantified.

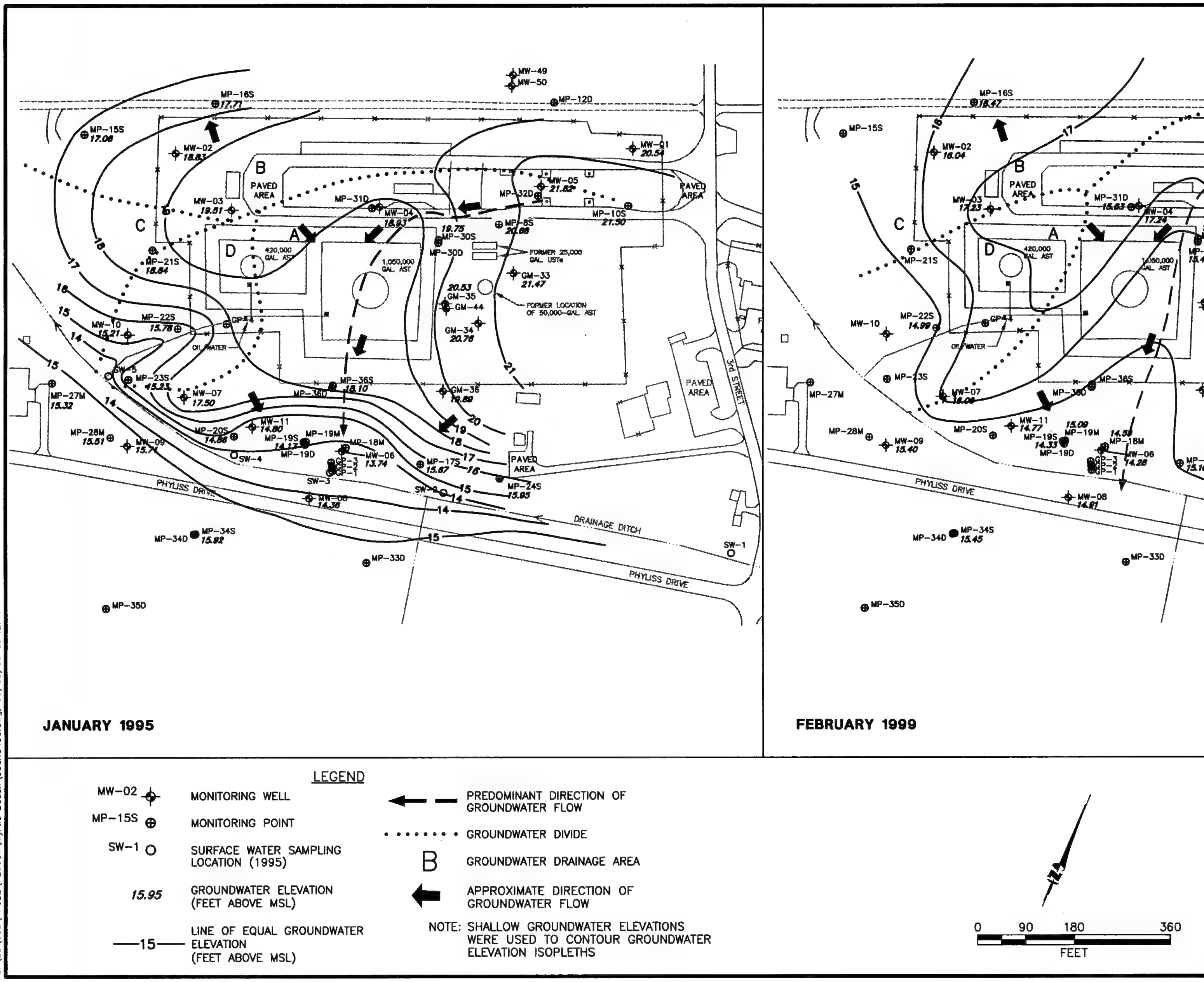

FIGURE 2

SHALLOW GROUNDWATER CONTOUR MAPS

POL Bulk Fuel Storage Area
Intrinsic Remediation CAS Addendum
Myrtle Beach AFB, South Carolina

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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An average hydraulic conductivity of 2.8 feet per day (ft/day) and an effective porosity of 0.2 were used to calculate an average groundwater advective velocity for the site in the Final CAS. Given an average hydraulic gradient of 0.01 ft/ft in 1995, an average advective groundwater velocity of 0.14 ft/day, or approximately 51 feet per year (ft/yr) was calculated from the source area to the south drainage ditch. Similarly for 1999, given an average hydraulic gradient of 0.006 ft/ft, an average advective groundwater velocity of 0.084 ft/day, or 31 ft/yr was calculated for the same flow path.

Vertical gradients also were calculated for the site in 1995. A downward vertical gradient exists across most of the site, ranging from 0.0 to 0.25 ft/ft as measured in 1995. However, an upward vertical gradient was measured in the area of the south drainage ditch. Data for February 1999 indicate similar trends in downward gradients near the source area, and upward gradients near the southern drainage ditch.

2.2 Total BTEX in Groundwater

BTEX compounds were detected in groundwater samples from 21 of the 28 monitoring wells included in the February 1999 sampling event. BTEX concentrations in groundwater are summarized in Table 3. In order to evaluate trends in BTEX concentrations and distribution through time, the areal distributions of total BTEX in shallow groundwater for January 1995 and February 1999 are presented on Figure 3. For all clustered well locations, the sample from the shallow well had the highest BTEX concentration relative to deeper well pairs. Therefore, where there were multiple BTEX concentrations at a well cluster, the shallow well concentration was used to plot BTEX isopleths on Figure 3.

Downgradient monitoring well locations MW-09, MP-35D, MW-08, and MP-17S exhibited low BTEX concentrations ranging from 0.95 to 15.8 micrograms per liter (μg/L) in January 1995. In February 1999, these same locations all had BTEX concentrations below the limit of quantitation (i.e., less than 1 μg/L). However, BTEX concentrations within the downgradient toe of the plume on the southern side of the drainage ditch and Phyliss Drive increased at locations MP-34S (9.79 μg/L to 246 μg/L) and MP-34D (2.24 μg/L to 31.4 μg/L).

While BTEX concentrations have decreased to below the limit of quantitation at well locations MW-09, MP-35D, MW-08, and MP-17S; a significant increase in BTEX concentrations has occurred at monitoring point cluster MP-34S and MP-34D. Based on the 10 μg/L contours shown in Figure 3, the BTEX plume has expanded approximately 100 feet across Phyliss Drive Between 1995 and 1999.

The observed BTEX plume configuration is similar to that predicted by the Bioplume II model presented in the Final CAS, with the notable exception of the increase in BTEX concentrations at monitoring point pair MP-34S and MP-34D. Concentrations of BTEX in the downgradient portion of the plume at this location are greater than predicted by the model. This difference can be accounted for by the amount of BTEX mass discharging to the southern drainage ditch paralleling Phyliss Drive. The model assumes that BTEX mass will discharge to the ditch at the ditch boundary. Modeled discharge of BTEX mass to the ditch appears to be greater than the

TABLE 3
SUMMARY OF FUEL HYDROCARBONS AND MTBE DETECTED IN GROUNDWATER AND SURFACE WATER SAMPLES
POL BULK FUEL STORAGE AREA
INTRINSIC REMEDIATION CAS ADDENDUM
MYRTLE BEACH AFB, SOUTH CAROLINA

Sample Location	Sample Date	MTBE (µg/L)[a/]	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	p-Xylene (µg/L)	m-Xylene (µg/L)	o-Xylene (µg/L)	Total Xylenes (µg/L)	Total BTEX (µg/L)	Fuel Carbon (µg/L)
MW-01	Apr-94	NA[b/]	ND[c/]	ND	ND	NR[d/]	NR	NR	ND	ND	NA
	Jan-95	NA	ND	ND	ND	BLQ[e/]	BLQ	ND	BLQ	BLQ	BLQ
	Feb-99	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
MW-02	Apr-94	NA	560	ND	ND	NR	NR	NR	ND	560	NA
	Jan-95	NA	289	ND	1.98	1.37	3.76	1.89	7.02	298	418
	Feb-99	1.30	178	BLQ	2.5	1.6	1.8	BLQ	3.40	184	NA
MW-03	Apr-94	NA	5.9	0.73	ND	NR	NR	NR	ND	6.63	NA
	Jan-95	NA	41	ND	1.45	BLQ	BLQ	ND	BLQ	42.5	403
	Feb-99	BLQ	9	BLQ	BLQ	ND	ND	ND	ND	9	NA
MW-04	Jan-95	NA	2,310	1,130	401	379	736	383	1,500	5,340	5,840
	Feb-99	BLQ	294	114	268	391	939	159	1,490	2,170	NA
MW-05	Jan-95	NA	9,530	6,060	506	426	1,020	728	2,170	18,300	18,300
MW-06	Apr-94	NA	400	280	3100	NR	NR	NR	47	3,830	NA
	Jan-95	NA	419	61.7	300	764	1,530	776	3,070	3,850	5,450
	Feb-99	28.0	271	18.7	778	891	2,580	269	3,740	4,810	NA
MW-07	Apr-94	NA	ND	ND	ND	NR	NR	NR	ND	ND	NA
	Jan-95	NA	3.39	3.04	1.07	1.81	5.39	1.48	8.68	16.2	35.1
	Feb-99	ND	BLQ	ND	38.4	69.6	37.6	ND	107	146	NA
MW-08	Apr-94	NA	ND	ND	ND	NR	NR	NR	ND	ND	NA
	Jan-95	NA	BLQ	0.953	ND	ND	BLQ	ND	BLQ	0.953	6.07
	Feb-99	ND	BLQ	ND	ND	BLQ	BLQ	ND	BLQ	BLQ	NA

TABLE 3 (Continued)
SUMMARY OF FUEL HYDROCARBONS AND MTBE DETECTED IN GROUNDWATER AND SURFACE WATER SAMPLES
POL BULK FUEL STORAGE AREA
INTRINSIC REMEDIATION CAS ADDENDUM
MYRTLE BEACH AFB, SOUTH CAROLINA

Sample Location	Sample Date	MTBE (µg/L)[a]	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	p-Xylene (µg/L)	m-Xylene (µg/L)	o-Xylene (µg/L)	Total Xylenes (µg/L)	Total BTEX (µg/L)	Fuel Carbon (µg/L)
MW-09	Apr-94	NA	ND	ND	ND	NR	NR	NR	ND	ND	NA
	Jan-95	NA	ND	BLQ	ND	BLQ	2.96	1.04	4.00	4.00	11.6
	Feb-99	ND	BLQ	ND	ND	ND	BLQ	ND	BLQ	BLQ	NA
MW-10	Apr-94	NA	ND	ND	1.8	NR	NR	NR	ND	1.8	NA
	Jan-95	NA	ND	1.66	ND	BLQ	BLQ	ND	BLQ	1.66	8.12
MW-11	Apr-94	NA	350	98	2400	NR	NR	NR	ND	2,850	NA
	Jan-95	NA	282	23.5	34	363	974	495	1,830	2,170	2,920
	Feb-99	BLQ	27.3	1.3	1.8	21.1	45.3	35.4	102	132	NA
MW-49	Jan-95	NA	BLQ	ND	ND	BLQ	2.21	BLQ	2.21	2.21	BLQ
MW-50	Jan-95	NA	BLQ	ND	ND	1.43	4.67	1.86	7.96	7.96	14.6
MP-8S	Jan-95	NA	393	141	105	89.6	208	109	407	1,050	1,850
	Feb-99	57.7	950	662	366	410	1,070	348	1,830	3,810	NA
MP-10S	Jan-95	NA	3.68	2.21	2.22	2.38	5.48	1.39	9.25	17.4	44.5
	Jan-95[b]	NA	4.05	4.48	3.2	3.3	5.98	2.32	11.6	23.3	58.1
	Feb-99	2.7	23.9	2.9	62.5	104	156	1.3	261	351	NA
MP-12D	Jan-95	NA	ND	5.51	ND	ND	BLQ	ND	BLQ	5.51	5.42
	Feb-99	ND	BLQ	BLQ	1.9	3.8	2.6	BLQ	6.4	6.4	NA
MP-15S	Jan-95	NA	60.6	BLQ	ND	ND	BLQ	ND	BLQ	60.6	95

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TABLE 3 (Continued)
SUMMARY OF FUEL HYDROCARBONS AND MTBE DETECTED IN GROUNDWATER AND SURFACE WATER SAMPLES
POL BULK FUEL STORAGE AREA
INTRINSIC REMEDIATION CAS ADDENDUM
MYRTLE BEACH AFB, SOUTH CAROLINA

Sample Location	Sample Date	MTBE (µg/L)[a/]	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	p-Xylene (µg/L)	m-Xylene (µg/L)	o-Xylene (µg/L)	Total Xylenes (µg/L)	Total BTEX (µg/L)	Fuel Carbon (µg/L)
MP-16S	Jan-95	NA	3.28	66.3	3.79	5.55	13.9	10	29.5	103	101
	Feb-99	ND	BLQ	BLQ	ND	ND	BLQ	ND	BLQ	BLQ	NA
	Feb-99[f/]	ND	BLQ	BLQ	ND	ND	BLQ	ND	BLQ	BLQ	NA
MP-17S	Jan-95	NA	BLQ	2.27	1.55	1.81	6.33	3.86	12.0	15.8	19.9
	Jan-95[i/]	NA	2.11	1.95	2.66	2.62	6.43	4.37	13.4	20.1	18.2
	Feb-99	ND	BLQ	ND	ND	ND	BLQ	ND	BLQ	BLQ	NA
MP-18M	Jan-95	NA	ND	11	ND	ND	BLQ	ND	BLQ	11	281
	Feb-99	BLQ	BLQ	1.7	BLQ	BLQ	1.2	BLQ	1.2	2.9	NA
MP-19S	Jan-95	NA	644	453	783	735	1,420	1,100	3,260	5,140	6,390
	Feb-99	31.4	592	80.1	629	673	2,090	500	3,260	4,560	NA
MP-19M	Jan-95	NA	4.45	20.4	ND	BLQ	BLQ	ND	BLQ	24.9	163
	Feb-99	BLQ	99.7	17.5	103	99	317	101	517	737	NA
MP-19D	Jan-95	NA	ND	BLQ	ND	ND	ND	ND	ND	BLQ	BLQ
	Feb-99	ND	3.0	BLQ	BLQ	3.1	8.4	ND	11.5	14.5	NA
	Feb-99[f/]	ND	2.8	BLQ	BLQ	3.0	7.7	ND	10.7	13.5	NA
MP-20S	Jan-95	NA	BLQ	BLQ	BLQ	BLQ	ND	ND	BLQ	BLQ	BLQ
MP-21S	Jan-95	NA	ND	ND	ND	ND	BLQ	ND	BLQ	BLQ	BLQ
	Jan-95[i/]	NA	BLQ	1.8	BLQ	ND	1.22	ND	1.22	3.02	3.26
MP-22S	Jan-95	NA	ND	BLQ	BLQ	0.989	2.63	1.44	5.06	5.06	12.4
	Feb-99	ND	BLQ	ND	ND	1.2	ND	BLQ	1.2	1.2	NA

TABLE 3 (Continued)
SUMMARY OF FUEL HYDROCARBONS AND MTBE DETECTED IN GROUNDWATER AND SURFACE WATER SAMPLES
POL BULK FUEL STORAGE AREA
INTRINSIC REMEDIATION CAS ADDENDUM
MYRTLE BEACH AFB, SOUTH CAROLINA

Sample Location	Sample Date	MTBE (μg/L)[a/]	Benzene (μg/L)	Toluene (μg/L)	Ethylbenzene (μg/L)	p-Xylene (μg/L)	m-Xylene (μg/L)	o-Xylene (μg/L)	Total Xylenes (μg/L)	Total BTEX (μg/L)	Fuel Carbon (μg/L)
MP-23S	Jan-95	NA	ND	ND	ND	ND	BLQ	ND	BLQ	BLQ	BLQ
MP-24S	Jan-95	NA	ND	ND	ND	ND	BLQ	ND	BLQ	BLQ	BLQ
MP-27M	Jan-95	NA	ND	ND	ND	BLQ	1.67	BLQ	1.67	1.67	5.63
MP-28M	Jan-95	NA	ND	BLQ	BLQ	ND	0.963	ND	0.963	0.963	4.21
MP-30S	Jan-95	NA	571	18.3	495	596	944	10.7	1,550	2,640	4,320
	Feb-99	29.5	288	14.4	605	664	1,360	BLQ	2,020	2,930	NA
MP-30D	Jan-95	NA	16.5	2.64	27.9	26.2	70.1	1.68	98.0	145	485
	Feb-99	20.3	291	BLQ	7.4	26.8	12.2	BLQ	39.0	337	NA
MP-31D	Jan-95	NA	BLQ	2.57	0.985	ND	1.78	ND	1.78	5.34	26.1
	Feb-99	ND	44.3	BLQ	1.8	1.5	2.7	BLQ	4.2	50.3	NA
MP-32D	Jan-95	NA	24.2	22.6	4.16	4.37	9.04	3.33	16.7	67.7	78.4
	Feb-99	ND	BLQ	BLQ	ND	ND	BLQ	ND	BLQ	BLQ	NA
MP-33D	Jan-95	NA	1.32	1.08	ND	ND	BLQ	ND	BLQ	2.4	4.25
MP-34S	Jan-95	NA	2.44	6.26	BLQ	ND	1.09	ND	1.09	9.79	8.44
	Jan-95[b/]	NA	2.31	6.3	ND	ND	1.26	ND	1.26	9.87	8.15
	Feb-99	ND	3.4	ND	47.5	86.7	108	ND	195	246	NA
MP-34D	Jan-95	NA	2.24	BLQ	BLQ	ND	BLQ	ND	BLQ	2.24	3.65
	Feb-99	ND	31.4	ND	ND	ND	ND	ND	ND	31.4	NA

TABLE 3 (Continued)
SUMMARY OF FUEL HYDROCARBONS AND MTBE DETECTED IN GROUNDWATER AND SURFACE WATER SAMPLES
POL BULK FUEL STORAGE AREA
INTRINSIC REMEDIATION CAS ADDENDUM
MYRTLE BEACH AFB, SOUTH CAROLINA

Sample Location	Sample Date	MTBE (µg/L)[a/]	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	p-Xylene (µg/L)	m-Xylene (µg/L)	o-Xylene (µg/L)	Total Xylenes (µg/L)	Total BTEX (µg/L)	Fuel Carbon (µg/L)
MP-35D	Jan-95	NA	2.21	0.966	ND	ND	ND	ND	ND	3.18	3.41
	Feb-99	ND	BLQ	BLQ	BLQ	BLQ	BLQ	ND	BLQ	BLQ	NA
MP-36S	Jan-95	NA	1,180	4,230	1,110	1,080	3,100	1,080	5,260	11,800	13,800
	Feb-99	22.4	1,090	401	1,480	1,310	3,440	2,080	6,830	9,800	NA
MP-36D	Jan-95	NA	3.27	0.946	ND	ND	1.2	ND	1.2	5.42	5.18
	Jan-95[f/]	NA	3.33	2.53	ND	ND	1.62	ND	1.62	7.48	9.97
	Feb-99	ND	2.8	1.2	9.3	9.9	30.4	8.5	48.8	62.1	NA
GM-33	Apr-94	NA	ND	ND	ND	NR	NR	NR	ND	ND	NA
	Jan-95	NA	BLQ	ND	ND	ND	ND	ND	ND	BLQ	BLQ
GM-34	Apr-94	NA	ND	ND	ND	NR	NR	NR	ND	ND	NA
	Jan-95	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND
GM-35	Apr-94	NA	ND	3.6	18J[g/]	NR	NR	NR	ND	21.6	NA
	Jan-95	NA	0.944	ND	ND	1.43	1.14	ND	2.57	3.51	45.9
GM-36	Apr-94	NA	ND	7.2	140J	NR	NR	NR	ND	147	NA
	Jan-95	NA	ND	ND	2.6	23.6	51.9	7	82.5	85.1	200
GM-44	Apr-94	NA	ND	ND	ND	NR	NR	NR	ND	ND	NA
	Jan-95	NA	BLQ	BLQ	ND	1.45	ND	ND	1.45	1.45	22.8
GP1S	Jan-95	NA	663	29.6	985	1,060	3,270	7.23	4,340	6,010	10,400
GP1D	Jan-95	NA	557	6.27	50	659	1,870	49.7	2,580	3,190	4,640

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TABLE 3 (Continued)
SUMMARY OF FUEL HYDROCARBONS AND MTBE DETECTED IN GROUNDWATER AND SURFACE WATER SAMPLES
POL BULK FUEL STORAGE AREA
INTRINSIC REMEDIATION CAS ADDENDUM
MYRTLE BEACH AFB, SOUTH CAROLINA

Sample Location	Sample Date	MTBE (µg/L)[a/]	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	p-Xylene (µg/L)	m-Xylene (µg/L)	o-Xylene (µg/L)	Total Xylenes (µg/L)	Total BTEX (µg/L)	Fuel Carbon (µg/L)
GP2S	Jan-95	NA	957	20.5	512	1,010	2,950	11.9	3,970	5,460	7,970
GP3S	Jan-95	NA	1,160	237	1,200	1,180	3,530	574	5,280	7,880	18,200
GP3D	Jan-95	NA	436	25.1	269	830	2,130	160	3,120	3,850	6,390
SW-1	Jan-95	NA	17.1	32.4	5.69	6.79	10.9	9.29	27.0	82.2	112
	Jan-95[f/]	NA	19.8	38	6.0	7.15	12.2	10.3	29.7	93.5	120
SW-2	Jan-95	NA	BLQ	BLQ	ND	ND	1.06	ND	1.06	1.06	1.79
	Jan-95[f/]	NA	BLQ	BLQ	ND	ND	1.03	ND	1.03	1.03	2.96
SW-3	Jan-95	NA	434	13.2	144	274	700	32.2	1,010	1,600	2,090
SW-4	Jan-95	NA	5.56	BLQ	2.14	4.8	9.69	4.06	18.6	26.3	44.7
SW-5	Jan-95	NA	ND	ND	ND	ND	1.05	ND	1.05	1.05	0.89

[a/] µg/L = micrograms per Liter.
[b/] NA = Not Analyzed.
[c/] ND = Not Detected.
[d/] NR = Not Reported.
[e/] BLQ = Below Limit of Quanititation, 1 part per billion.
[f/] Dup = Duplicate Sample.
[g/] J = Estimated quantitation based upon QC data.

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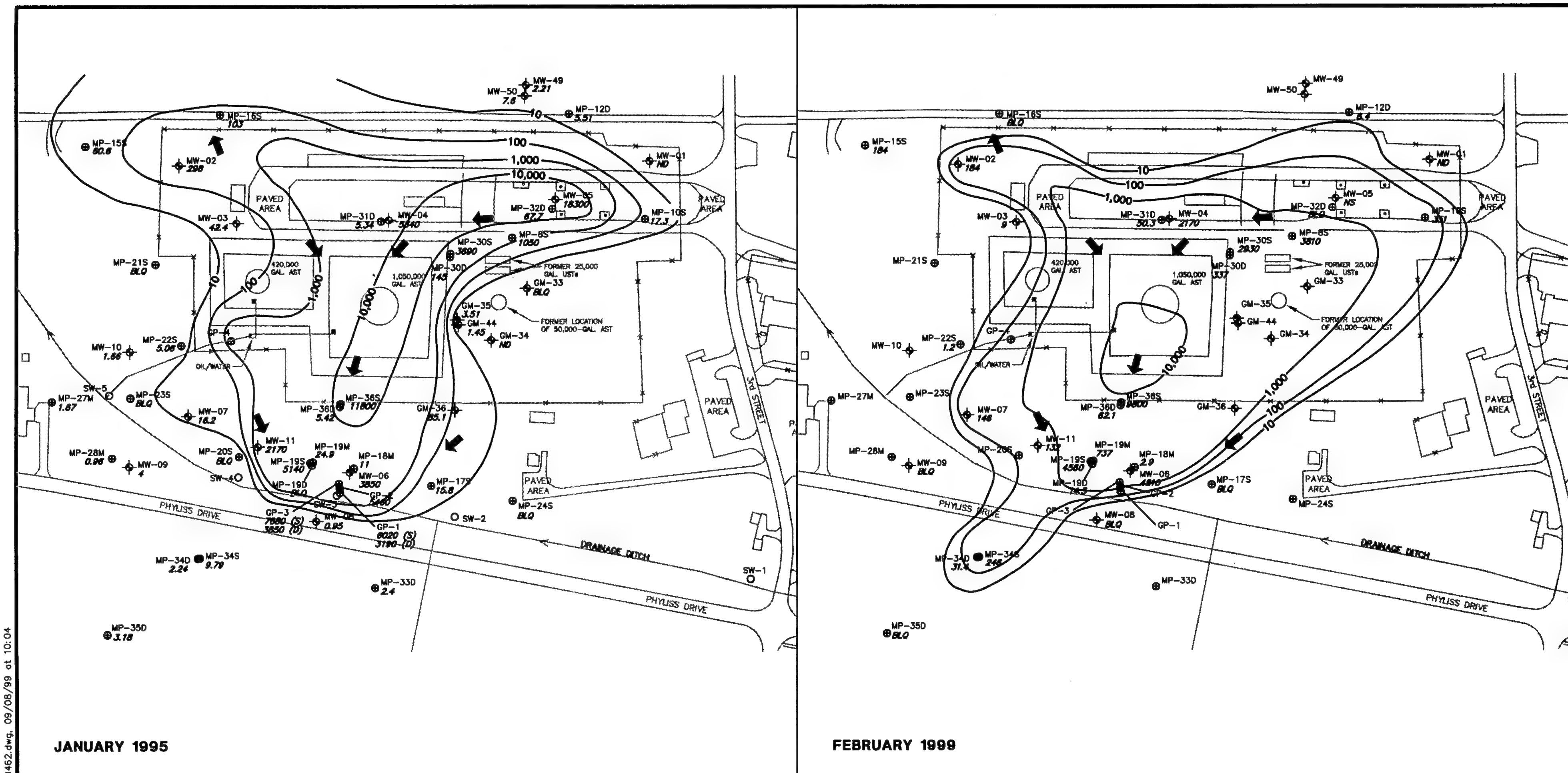

LEGEND

MW-02 298	MONITORING WELL WITH TOTAL BTEX CONCENTRATION ($\mu g/L$)	(arrow)	APPROXIMATE DIRECTION OF GROUNDWATER FLOW
MP-15S 60.6	MONITORING POINT WITH TOTAL BTEX CONCENTRATION ($\mu g/L$)	—10—	LINE OF EQUAL TOTAL BTEX CONCENTRATION ($\mu g/L$) (DASHED WHERE INFERRED) CONTOUR INTERVAL = VARIABLE
SW-1	SURFACE WATER SAMPLING LOCATION (1995)	*NS*	NOT SAMPLED
ND	NOT DETECTED		
BLQ	BELOW LEVEL OF QUANTIFICATION		

0 90 180 360
FEET

FIGURE 3

TOTAL BTEX ISOPLETH MAP FOR SHALLOW GROUNDWATER

POL Bulk Fuel Storage Area
Intrinsic Remediation CAS Addendum
Myrtle Beach AFB, South Carolina

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Denver, Colorado

observed conditions. Some BTEX mass is apparently migrating beneath the ditch and Phyliss Drive in the vicinity of monitoring point pair MP-34S and MP-34D.

Concentrations of BTEX near the source area appear to have decreased since 1995. The concentration of BTEX in 1995 at MP-36S was 11,800 μg/L, while in 1999 the BTEX concentration was 9,800 μg/L. The source area well with the highest detected BTEX concentration in January 1995 was not sampled in February 1999 due to the high volume of LNAPL encountered in the well. BTEX concentrations in a nearby well MP-32D, screened in a deeper interval, decreased from 67.7 μg/L in January 1995 to below detection in February 1999. This suggests that BTEX mass flux from the source area has reached steady state, and may have started to decrease. BTEX concentrations in the northwestern lobe of the plume also appear to be decreasing. BTEX concentrations in well MW-02 decreased from 298 μg/L in January 1995 to 184 μg/L in February 1999. Reductions or fluctuations in source area concentrations may be attributed to natural source weathering or the effects of fluctuating groundwater levels.

Vertical profiles of BTEX concentrations along the approximate centerline of the plume are shown on Figures 5 and 6 for January 1995 and February 1999. Review of these profiles suggests that BTEX concentrations are increasing in the downgradient toe of the plume (MP-34S and MP-34D) and vertically in a downward direction (MP-19M, MP-19D, and MP-36D). BTEX concentrations for monitoring well cluster MP-19 (MP-19S, MP-19M, and MP-19D) for January 1995 and February 1999 are listed on Table 3 and shown on Figures 5 and 6. While the total BTEX concentration for the shallow monitoring point (MP-19S) has decreased from 5,140 μg/L in 1995 to 4,560 μg/L in 1999, total BTEX concentrations have increased at intermediate monitoring point MP-19M (from 24.9 μg/L to 737 μg/L) and at deep monitoring point MP-19D (from below the limit of quantitation to 14.5 μg/L). Since 1995, the 10 and 100 μg/L isopleths all have shifted downward and downgradient indicating that significant BTEX mass has migrated both areally and vertically in the downgradient direction.

2.3 Benzene in Groundwater

Of the four compounds that comprise BTEX, benzene is the primary risk driver at the POL due to its higher chemical toxicity and corresponding lower regulatory action concentration. The areal extent of benzene in January 1995 and February 1999 is shown on Figure 7. Comparison of Figure 7 with Figure 3 shows that the extent and expansion of the benzene plume is similar to that of the BTEX plume (Figure 3).

Figure 8 plots benzene concentrations over time at select wells that are representative of conditions near the source area (MP-8S), and downgradient along the axis of the benzene plume in shallow wells (MW-02, MW-06, MW-11). While benzene concentrations have decreased along the plume axis, benzene has increased in concentration at source area well MP-8S. This suggests that while natural attenuation may be acting to reduce benzene concentrations along the plume axis, the benzene source has not attenuated and a significant mass flux of benzene to groundwater continues.

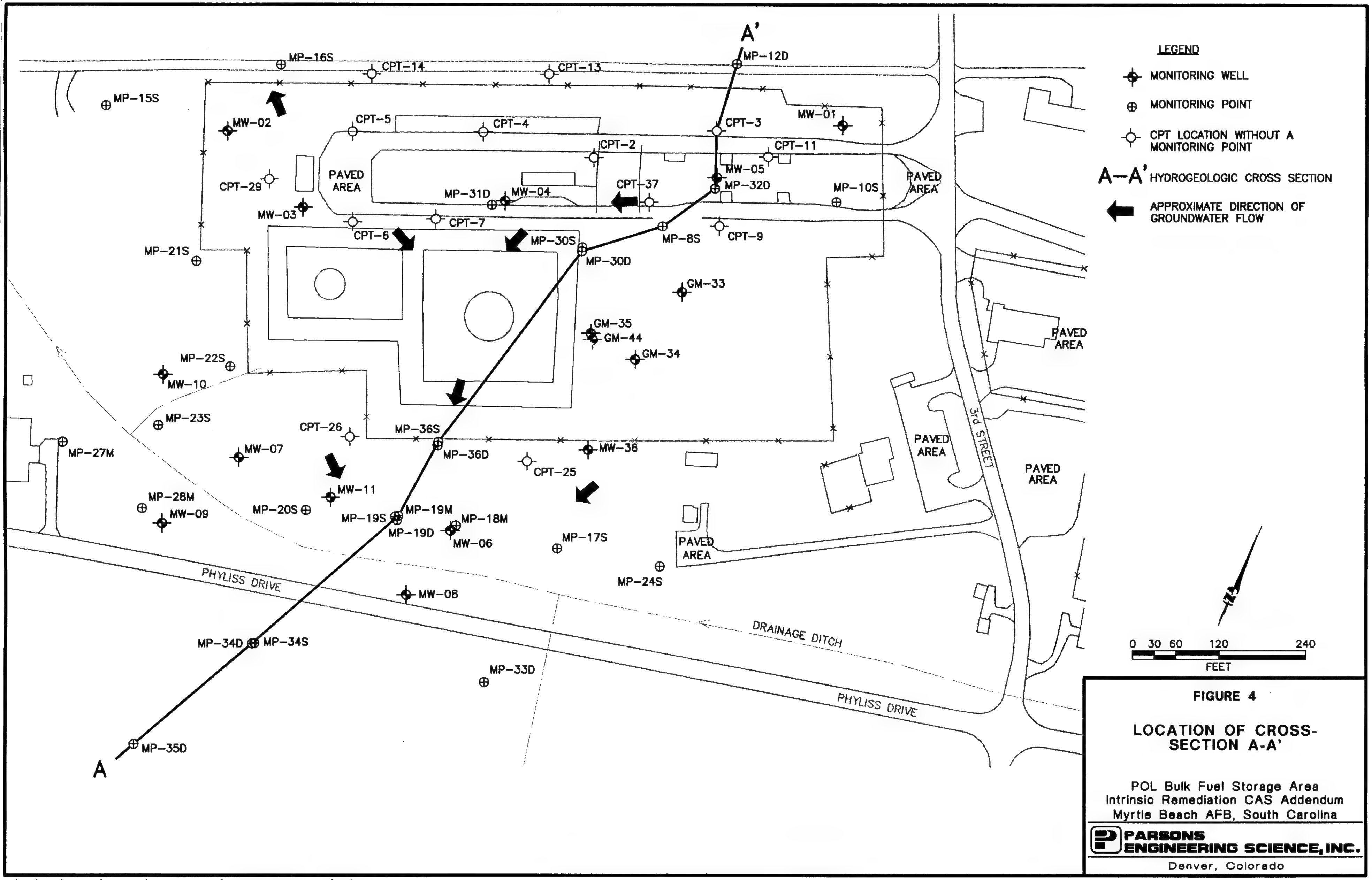

FIGURE 4

LOCATION OF CROSS-SECTION A-A'

POL Bulk Fuel Storage Area
Intrinsic Remediation CAS Addendum
Myrtle Beach AFB, South Carolina

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Denver, Colorado

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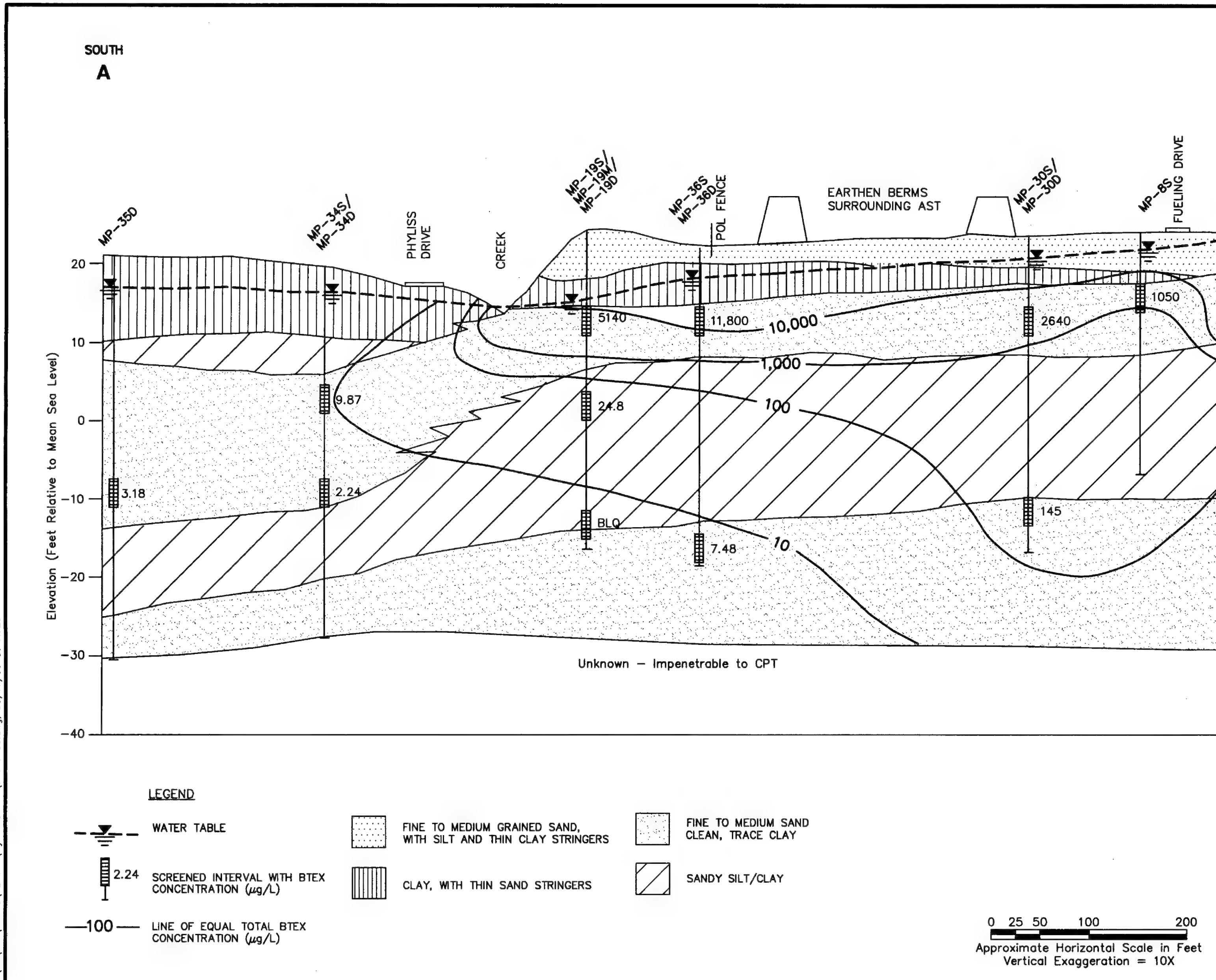

FIGURE 5

CROSS-SECTION A-A'
TOTAL BTEX ISOPLETHS
FOR GROUNDWATER
JANUARY 1995

POL Bulk Fuel Storage Area
Intrinsic Remediation CAS Addendum
Myrtle Beach AFB, South Carolina

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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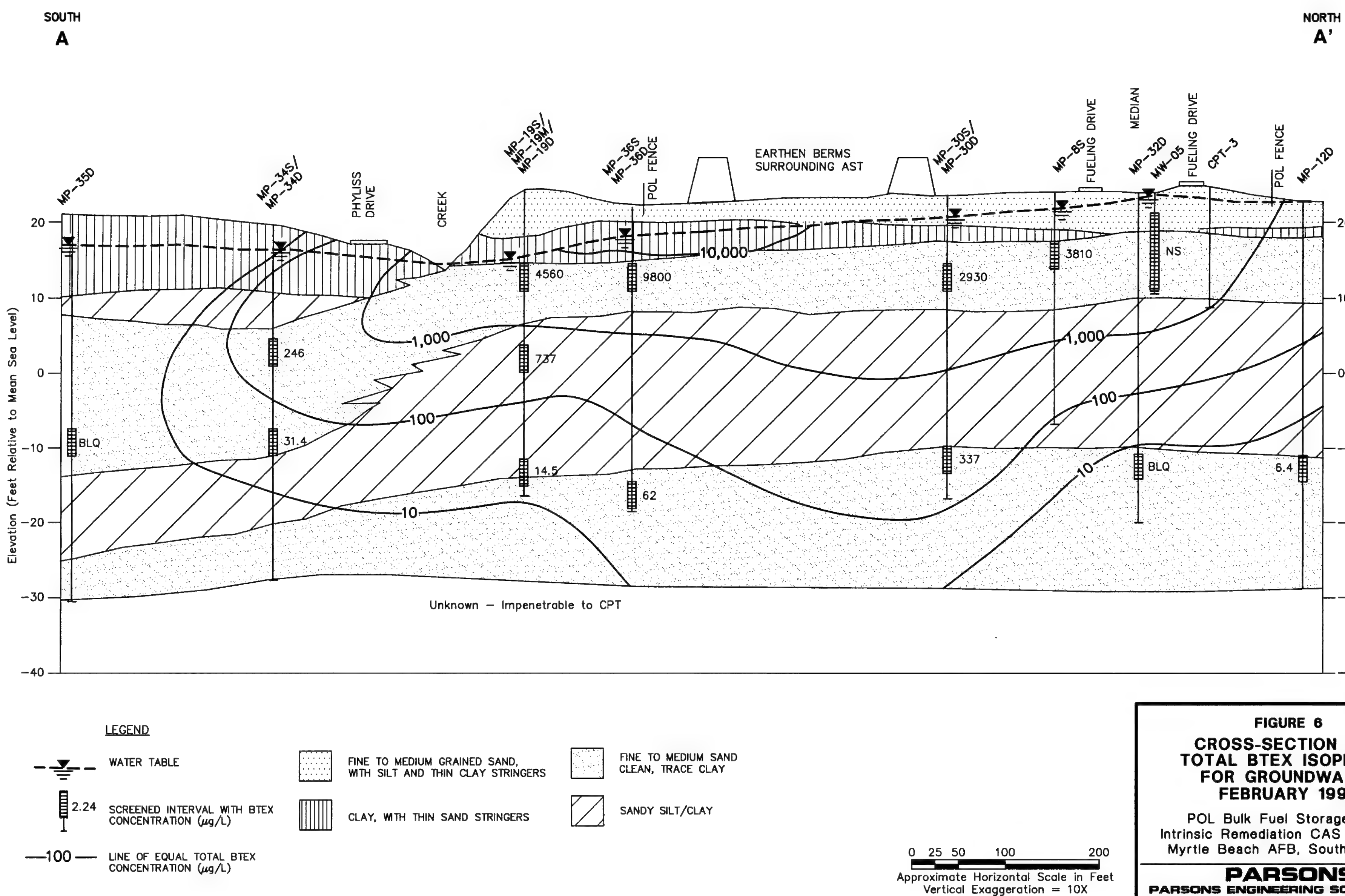

FIGURE 6

**CROSS-SECTION A-A'
TOTAL BTEX ISOPLETHS
FOR GROUNDWATER
FEBRUARY 1999**

POL Bulk Fuel Storage Area
Intrinsic Remediation CAS Addendum
Myrtle Beach AFB, South Carolina

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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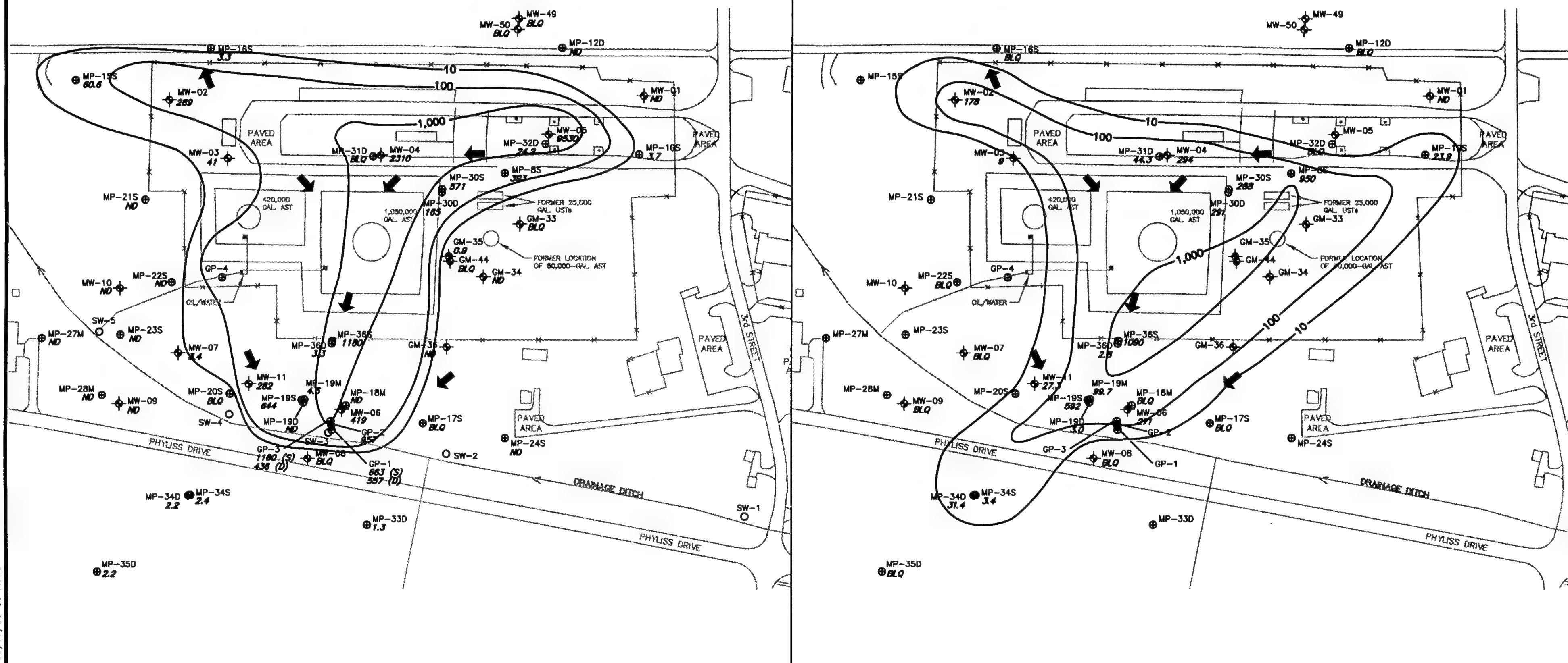

JANUARY 1995

FEBRUARY 1999

LEGEND

MW-02 298 — MONITORING WELL WITH BENZENE CONCENTRATION (μg/L)

MP-15S 60.6 — MONITORING POINT WITH BENZENE CONCENTRATION (μg/L)

SW-1 — SURFACE WATER SAMPLING LOCATION (1995)

ND NOT DETECTED

BLQ BELOW LEVEL OF QUANTIFICATION

APPROXIMATE DIRECTION OF GROUNDWATER FLOW

—10— LINE OF EQUAL TOTAL BENZENE CONCENTRATION (μg/L) (DASHED WHERE INFERRED) CONTOUR INTERVAL = VARIABLE

0 90 180 360
FEET

FIGURE 7

BENZENE IN GROUNDWATER

POL Bulk Fuel Storage Area
Intrinsic Remediation CAS Addendum
Myrtle Beach AFB, South Carolina

PARSONS
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Denver, Colorado

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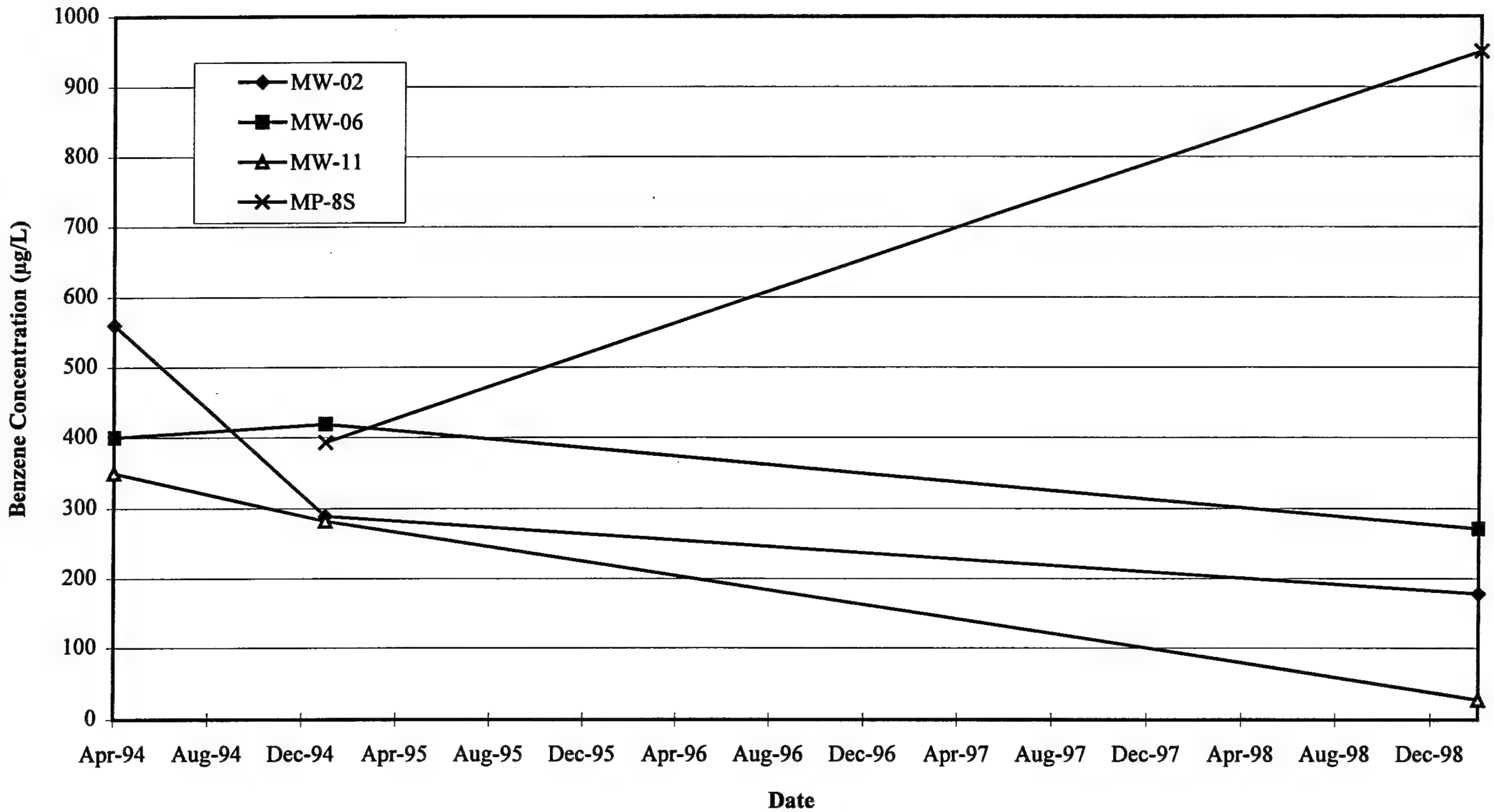
FIGURE 8
BENZENE CONCENTRATION vs.TIME
POL BULK FUEL STORAGE AREA
INTRINSIC REMEDIATION CAS ADDENDUM
MYRTLE BEACH AFB, SOUTH CAROLINA



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Concentrations of benzene (Table 3) have increased between 1995 and 1999 in deep monitoring points MP-19D (not detected to 3.0 μg/L), MP-30D (16.5 μg/L to 291 μg/L), MP-31D (below the limit of quantitation to 44.3 μg/L), and MP-34D (2.24 μg/L to 31.4 μg/L). This increase in benzene concentrations in deep monitoring points over time confirms the observation that the BTEX and benzene plumes are migrating in a downward vertical direction.

2.4 Trimethylbenzenes and Tetramethylbenzenes in Groundwater

TMBs also were analyzed as part of the February sampling 1999 event and results are presented in Table 4. TMB and tetramethylbenzenes (TEMBs) are water-soluble fuel constituents considered to be recalcitrant to biological degradation under anaerobic conditions. Therefore, they are commonly used as tracer compounds to calculate BTEX degradation under anaerobic conditions. The extent of TMBs and TEMBs detected in groundwater is less than total BTEX or benzene, possibly due to the relatively higher retardation of TMBs, or their susceptibility to aerobic degradation that may occur at the BTEX plume periphery. Concentrations of total TMBs have increased over time in groundwater at locations closer to the source area (MW-04, MW-06, MP8S, MP10S, MP19S, MP19M. MP30S, and MP36S).

2.5 MTBE in Groundwater

Groundwater samples collected during the February 1999 sampling event were analyzed for MTBE for the first time. MTBE is a fuel oxygenate added to fuel to increase the octane rating and to reduce combustion emissions. MTBE typically migrates at a faster rate than fuel hydrocarbons in groundwater due to a relatively lower affinity for soil sorption (retardation). Although no historical site data exist for MTBE, the greatest concentrations of MTBE were detected in groundwater samples collected from the BTEX plume interior. MTBE was not detected in samples collected from perimeter wells.

The earliest known fuel release at the site dates back to the 1960's, while MTBE was first used as a fuel additive in the late 1970's to early 1980's. Therefore, MTBE likely was introduced as a site-related contaminant at a later date, with a shorter time period for migration relative to BTEX. This may explain why MTBE is present within the BTEX plume interior, but not at the periphery of the BTEX plume as expected.

2.6 Inorganic Chemistry and Geochemical Indicators of Biodegradation

As discussed in the Final CAS, microorganisms obtain energy for cell production and maintenance by facilitating thermodynamically advantageous redox reactions involving the transfer of electrons from electron donors to available electron acceptors. This results in the oxidation of the electron donor and the reduction of the electron acceptor. Electron donors at the former Myrtle Beach AFB POL are natural organic carbon and fuel hydrocarbon compounds. Fuel hydrocarbons are completely degraded or detoxified if they are utilized as the primary electron donor for microbial metabolism (Bouwer, 1992).

TABLE 4
SUMMARY OF FUEL TRACER COMPOUNDS DETECTED IN GROUNDWATER AND SURFACE WATER SAMPLES
POL BULK FUEL STORAGE AREA
INTRINSIC REMEDIATION CAS ADDENDUM
MYRTLE BEACH AFB, SOUTH CAROLINA

Sample Location	Sample Date	1,3,5-TMB[a/] (µg/L)[c/]	1,2,4-TMB (µg/L)	1,2,3-TMB (µg/L)	Total TMB (µg/L)	1,2,4,5-TEMB[b/] (µg/L)	1,2,3,5-TEMB (µg/L)	1,2,3,4-TEMB (µg/L)	Total TEMB (µg/L)
MW-01	Jan-95	ND[d/]	ND	ND	ND	ND	ND	ND	ND
	Feb-99	ND	ND	ND	ND	NA[e/]	NA	NA	NA
MW-02	Jan-95	ND	0.91	1.3	2.21	1.28	2.16	ND	3.44
	Feb-99	ND	<1[f/]	<1	<1	NA	NA	NA	NA
MW-03	Jan-95	ND	ND	ND	ND	ND	BLQ[g/]	BLQ	BLQ
	Jan-95[h/]	ND	2.25	2.08	4.33	ND	ND	ND	ND
	Feb-99	ND	<1	ND	<1	NA	NA	NA	NA
MW-04	Jan-95	89.9	269	182	541	12.8	18.1	24.3	55.2
	Feb-99	157	340	174	671	NA	NA	NA	NA
MW-05	Jan-95	100	442	227	769	12.7	28.8	28.1	69.6
MW-06	Jan-95	153	452	234	839	8.36	21.3	23.7	53.4
	Feb-99	260	645	278	1180	NA	NA	NA	NA
MW-07	Jan-95	ND	1.58	ND	1.58	ND	ND	ND	ND
	Feb-99	<1	<1	<1	<1	NA	NA	NA	NA
MW-08	Jan-95	ND	ND	ND	ND	ND	ND	ND	ND
	Feb-99	ND	ND	ND	ND	NA	NA	NA	NA

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TABLE 4 (Continued)
SUMMARY OF FUEL TRACER COMPOUNDS DETECTED IN GROUNDWATER AND SURFACE WATER SAMPLES
POL BULK FUEL STORAGE AREA
INTRINSIC REMEDIATION CAS ADDENDUM
MYRTLE BEACH AFB, SOUTH CAROLINA

Sample Location	Sample Date	1,3,5-TMB[a/] (µg/L)[c/]	1,2,4-TMB (µg/L)	1,2,3-TMB (µg/L)	Total TMB (µg/L)	1,2,4,5-TEMB[b/] (µg/L)	1,2,3,5-TEMB (µg/L)	1,2,3,4-TEMB (µg/L)	Total TEMB (µg/L)
MW-09	Jan-95	ND	ND	ND	ND	ND	ND	ND	ND
	Feb-99	ND	ND	ND	ND	NA	NA	NA	NA
MW-10	Jan-95	ND	0.941	ND	0.941	ND	ND	ND	ND
MW-11	Jan-95	76.9	209	107	393	8.99	14.5	15.7	39.2
	Feb-99	1.1	4.7	2.7	8.5	NA	NA	NA	NA
MW-49	Jan-95	ND	BLQ	ND	BLQ	ND	ND	ND	ND
MW-50	Jan-95	ND	BLQ	ND	BLQ	ND	ND	ND	ND
MP-8S	Jan-95	21.1	83.7	35.6	140	2.98	7.39	7.56	17.9
	Feb-99	173	557	258	988	NA	NA	NA	NA
MP-10S	Jan-95	BLQ	2.81	1.3	4.11	ND	ND	ND	ND
	Jan-95[h/]	2.53	4	2.35	8.88	ND	ND	ND	ND
	Feb-99	6.2	21.1	15.6	42.9	NA	NA	NA	NA
MP-12D	Jan-95	ND	ND	ND	ND	ND	ND	ND	ND
	Feb-99	ND	ND	ND	ND	NA	NA	NA	NA
MP-15S	Jan-95	ND	BLQ	ND	BLQ	1.14	1.29	1.27	3.7

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TABLE 4 (Continued)
SUMMARY OF FUEL TRACER COMPOUNDS DETECTED IN GROUNDWATER AND SURFACE WATER SAMPLES
POL BULK FUEL STORAGE AREA
INTRINSIC REMEDIATION CAS ADDENDUM
MYRTLE BEACH AFB, SOUTH CAROLINA

Sample Location	Sample Date	1,3,5-TMB[a/] (µg/L)[c/]	1,2,4-TMB (µg/L)	1,2,3-TMB (µg/L)	Total TMB (µg/L)	1,2,4,5-TEMB[b/] (µg/L)	1,2,3,5-TEMB (µg/L)	1,2,3,4-TEMB (µg/L)	Total TEMB (µg/L)
MP-16S	Jan-95	BLQ	3.6	1.27	4.87	ND	ND	ND	ND
	Feb-99	ND	ND	ND	ND	NA	NA	NA	NA
MP-17S	Jan-95	ND	ND	ND	ND	ND	ND	ND	ND
	Jan-95[h/]	ND	ND	ND	ND	ND	ND	ND	ND
	Feb-99	ND	ND	ND	ND	NA	NA	NA	NA
MP-18M	Jan-95	ND	ND	ND	ND	ND	ND	35.1	35.1
	Feb-99	ND	<1	<1	<1	NA	NA	NA	NA
MP-19S	Jan-95	144	427	231	802	7.86	19.5	22.4	49.8
	Feb-99	172	454	204	830	NA	NA	NA	NA
MP-19M	Jan-95	ND	ND	ND	ND	3.76	ND	7.21	11.0
	Feb-99	14.4	41.8	22.7	78.9	NA	NA	NA	NA
MP-19D	Jan-95	ND	ND	ND	ND	ND	ND	1.05	1.05
	Feb-99	<1	2.1	1.0	3.1	NA	NA	NA	NA
MP-20S	Jan-95	ND	ND	ND	ND	ND	ND	ND	ND
MP-21S	Jan-95	ND	ND	ND	ND	ND	ND	ND	ND
	Jan-95[h/]	ND	ND	ND	ND	ND	ND	ND	ND

TABLE 4 (Continued)
SUMMARY OF FUEL TRACER COMPOUNDS DETECTED IN GROUNDWATER AND SURFACE WATER SAMPLES
POL BULK FUEL STORAGE AREA
INTRINSIC REMEDIATION CAS ADDENDUM
MYRTLE BEACH AFB, SOUTH CAROLINA

Sample Location	Sample Date	1,3,5-TMB[a] (µg/L)[c]	1,2,4-TMB (µg/L)	1,2,3-TMB (µg/L)	Total TMB (µg/L)	1,2,4,5-TEMB[b] (µg/L)	1,2,3,5-TEMB (µg/L)	1,2,3,4-TEMB (µg/L)	Total TEMB (µg/L)
MP-22S	Jan-95	ND	ND	ND	ND	ND	ND	0.927	0.927
	Feb-99	ND	2.9	<1	2.9	NA	NA	NA	NA
MP-23S	Jan-95	ND	ND	ND	ND	ND	ND	ND	ND
MP-24S	Jan-95	ND	ND	ND	ND	ND	ND	ND	ND
MP-27M	Jan-95	ND	ND	ND	ND	ND	ND	ND	ND
MP-28M	Jan-95	ND	ND	ND	ND	ND	ND	ND	ND
MP-30S	Jan-95	76	334	274	684	15.1	25.8	36.1	77
	Feb-99	129	392	367	888	NA	NA	NA	NA
MP-30D	Jan-95	15.2	40.5	19.4	75.1	2.03	4.77	4.78	11.6
	Feb-99	2.0	9.5	14.4	25.9	NA	NA	NA	NA
MP-31D	Jan-95	ND	3.12	2.18	5.3	ND	BLQ	BLQ	BLQ
	Feb-99	<1	1.4	1.2	2.6	NA	NA	NA	NA
MP-32D	Jan-95	1.8	3.45	2.67	7.92	ND	ND	ND	ND
	Feb-99	ND	ND	ND	ND	NA	NA	NA	NA
MP-33D	Jan-95	ND	ND	ND	ND	ND	ND	ND	ND

TABLE 4 (Continued)
SUMMARY OF FUEL TRACER COMPOUNDS DETECTED IN GROUNDWATER AND SURFACE WATER SAMPLES
POL BULK FUEL STORAGE AREA
INTRINSIC REMEDIATION CAS ADDENDUM
MYRTLE BEACH AFB, SOUTH CAROLINA

Sample Location	Sample Date	1,3,5-TMB[a/] (µg/L)[c/]	1,2,4-TMB (µg/L)	1,2,3-TMB (µg/L)	Total TMB (µg/L)	1,2,4,5-TEMB[b/] (µg/L)	1,2,3,5-TEMB (µg/L)	1,2,3,4-TEMB (µg/L)	Total TEMB (µg/L)
MP-34S	Jan-95	ND	ND	ND	ND	ND	ND	ND	ND
	Jan-95[h/]	ND	ND	ND	ND	ND	ND	ND	ND
	Feb-99	ND	<1	<1	<1	NA	NA	NA	NA
MP-34D	Jan-95	ND	ND	ND	ND	ND	ND	ND	ND
	Feb-99	ND	ND	ND	ND	NA	NA	NA	NA
MP-35S	Jan-95	ND	ND	ND	ND	ND	ND	ND	ND
	Feb-99	ND	ND	ND	ND	NA	NA	NA	NA
MP-36S	Jan-95	235	726	351	1310	14.7	37.4	43.8	95.9
	Feb-99	363	913	396	1670	NA	NA	NA	NA
MP-36D	Jan-95	ND	ND	ND	ND	ND	ND	ND	ND
	Jan-95[h/]	ND	ND	ND	ND	ND	ND	ND	ND
	Feb-99	1.7	8.1	2.6	12.4	NA	NA	NA	NA
GM-33	Jan-95	ND	ND	ND	ND	ND	ND	ND	ND
GM-34	Jan-95	ND	ND	ND	ND	ND	ND	ND	ND
GM-35	Jan-95	ND	ND	2.41	2.41	ND	ND	BLQ	BLQ
GM-36	Jan-95	9.83	22.6	15.3	47.7	BLQ	1.52	1.84	3.36
GM-44	Jan-95	ND	ND	ND	ND	ND	ND	ND	ND

TABLE 4 (Continued)
SUMMARY OF FUEL TRACER COMPOUNDS DETECTED IN GROUNDWATER AND SURFACE WATER SAMPLES
POL BULK FUEL STORAGE AREA
INTRINSIC REMEDIATION CAS ADDENDUM
MYRTLE BEACH AFB, SOUTH CAROLINA

Sample Location	Sample Date	1,3,5-TMB[a] (µg/L)[c]	1,2,4-TMB (µg/L)	1,2,3-TMB (µg/L)	Total TMB (µg/L)	1,2,4,5-TEMB[b] (µg/L)	1,2,3,5-TEMB (µg/L)	1,2,3,4-TEMB (µg/L)	Total TEMB (µg/L)
GP1S	Jan-95	276	776	401	1450	17.4	43.5	46.4	107
GP1D	Jan-95	132	449	217	798	9.12	22	24.2	55.3
GP2S	Jan-95	199	656	316	1170	13.6	33.5	35.1	82.2
GP3S	Jan-95	431	1110	580	2120	39.1	134	116	289
GP3D	Jan-95	198	575	277	1050	14.3	35	35.1	84.4
SW-01	Jan-95	3.29	4.62	3.14	11.1	ND	ND	ND	ND
	Jan-95[h]	3.08	4.85	2.84	10.8	ND	ND	ND	ND
SW-2	Jan-95	ND	ND	ND	ND	ND	ND	ND	ND
	Jan-95[h]	ND	ND	ND	ND	ND	ND	ND	ND
SW-3	Jan-95	49.9	130	87.8	268	3.12	8.35	9.6	21.1
SW-4	Jan-95	2.86	3.28	2.82	8.96	ND	ND	ND	ND
SW-5	Jan-95	ND	ND	ND	ND	ND	ND	ND	ND

[a] TMB = Trimethylbenzene.
[b] TEMB = Tetramethylbenzene.
[c] µg/L = Micrograms per Liter.
[d] ND = Not Detected.
[e] NA = Not Analyzed.
[f] <1 = Below Indicated Quantitation Limit.
[g] BLQ = Below Quantitation Limit
[h] Indicates Duplicate Sample.

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Electron acceptors are elements or compounds that occur in relatively oxidized states and include oxygen, nitrate, ferric iron hydroxides, sulfate, and CO_2. Microorganisms preferentially utilize electron acceptors while metabolizing fuel hydrocarbons (Bouwer, 1992). DO is utilized first as the prime electron acceptor. After the DO is consumed, anaerobic microorganisms use electron acceptors in the following order of preference: nitrate, ferric iron, sulfate, and CO_2. Anaerobic destruction of the BTEX compounds is associated with the accumulation of fatty acids, production of methane, solubilization of iron (ferrous iron), and reduction of nitrate and sulfate (Cozzarelli et al., 1990; Wilson et al., 1990).

In the Final CAS it was suggested that biodegradation of fuel hydrocarbons is occurring at the site via the anaerobic processes of iron reduction, sulfate reduction, and methanogenesis. Low DO concentrations across the site indicated that aerobic respiration was limited. Because DO is recharged in the shallow groundwater by infiltration, a small, periodic contribution to the degradation of fuel constituents could be expected. Likewise, background nitrate concentrations are minimal and denitrification is not expected to contribute significantly to the attenuation of BTEX in site groundwater. Geochemical parameters for site groundwater are discussed below. Table 5 summarizes the geochemical parameters analyzed during the January 1995 and February 1999 sampling events.

Oxidation Reduction Potential

ORP, a measure of the relative tendency of a solution to accept or transfer electrons, was measured at 25 of the 28 wells sampled during February 1999. The dominant electron acceptor being reduced by microbes during BTEX oxidation is related to the ORP of the groundwater. ORP measured at the site are summarized in Table 5. Concentration isopleth maps of ORP measured at the site in January 1995 and February 1999 are presented on Figure 9. The ORPs measured in February 1999 at the site range from -170 millivolts (mV) to 143 mV.

Comparison of Figures 3 and 9 indicates that areas with low ORP coincide with areas characterized by high dissolved BTEX concentrations. Comparison of ORP values measured in January 1995 with those measured in February 1999 (Figure 9 and Table 5) suggests that the ORP of groundwater at the site may be increasing. In January 1995, ORP measured in 21 monitoring wells was less than -170 mV, while ORPs measured in February 1999 all were greater than -170 mV. Results of the February 1999 sampling event apparently indicate a more oxidizing groundwater environment across the site. However, ORP is very sensitive to methods of field measurement and sampling techniques. Therefore, additional ORP data are required to assess whether this is an actual trend, or a result of sampling methods or techniques.

Dissolved Oxygen

DO concentrations were measured at 25 of the 28 wells sampled during February 1999 (Table 5). DO concentrations across the site were less than 1 milligram per liter (mg/L) in 1995, and typically less than 1 mg/L in 1999. Wells screened in the deeper portion of the aquifer typically had lower DO concentrations than wells screened in the shallow zone. This discrepancy likely is due to the recharge of DO into shallow

TABLE 5
GROUNDWATER GEOCHEMICAL DATA
POL BULK FUEL STORAGE AREA
INTRINSIC REMEDIATION CAS ADDENDUM
MYRTLE BEACH AFB, SOUTH CAROLINA

Sample Location	Sample Date	Water Temp. (°C)[a]	pH (su)[b]	Conductivity (µmhos/cm)[c]	Redox Potential (mV)[d]	Dissolved Oxygen (mg/L)[e]	Nitrate + Nitrite (mg/L)	Ammonia (mg/L)	Ferrous Iron (mg/L)	Sulfate (mg/L)	Sulfide (mg/L)	Methane (mg/L)	Total Alkanity (mg/L)	Carbon Dioxide (mg/L)	Chloride (mg/L)	Total Organic Carbon (mg/L)
MW-01	Jan-95	16.7	5.9	281	-98	1.2	0.15	0.2	1.5	31.9	NA[f]	0.09	65	202	12.2	6.4
	Feb-99	17.1	6.2	251	132	1.8	0.12	< 0.1	0.2	23.7	< 0.1	0.033	80	80	9	8
MW-02	Jan-95	17.6	5.2	132	-202	0.1	<.05	<.05	2.3	8.74	2	2.06	7	356	17.6	5
	Feb-99	17.8	5.4	152	-129	0.2	< 0.1	< 0.1	2	13.2	1.5	1.26	40	190	12.5	5.34
MW-03	Jan-95	16.7	6	236	-216	0.1	<.05	1.3	38	4.28	NA	14.0	106	320	6.68	11.8
	Feb-99	17	6.2	223	-170	0	< 0.1	1.14	37	1.73	0.7	3.5	120	170	6.32	14.1
MW-04	Jan-95	19.8	5.9	438	-240	0.8	<.05	<.05	20	42	5	14.4	120	500	21.3	10.8
	Feb-99	19.7	6.1	303	-148	0.1	< 0.1	< 0.1	2	3.96	0.7	5.43	140	160	14.4	10.1
MW-05	Jan-95	18.3	5.3	220	-165	0.5	<.05	<.05	7	<.5	0.1	6.26	24	318	46	26.5
MW-06	Jan-95	20.2	5.5	104	-214	0.2	0.08	0.08	3.6	0.63	2	5.44	25	240	10.3	6
	Feb-99	18.1	6	176	-60	0.9	< 0.1	< 0.1	25	< 0.5	2	1.98	60	110	9	7.94
MW-07	Jan-95	18.5	4.9	180	-60	0.2	0.08	<.05	3.9	38.6	NA	0.018	5	320	17.7	10
	Feb-99	17.8	5.1	128	90	0.6	0.19	< 0.1	3	27	0.2	ND	10	110	9.85	6.34
MW-08	Jan-95	19.3	6.3	420	74	0.2	1.36	0.13	1.1	8.14	NA	1.47	160	164	20	6.5
	Feb-99	17.9	5	118	143	0.2	0.4	< 0.1	0.3	27.4	0.1	ND	10	90	6.25	4.03
MW-09	Jan-95	19.2	6.7	827	80	0.2	<.05	<.05	2	25.7	NA	0.872	377	384	7.95	7.7
	Feb-99	16.5	6.7	670	141	2.5	0.11	< 0.1	0.1	23.8	<0.1	0.011	320	60	7.69	5.96
MW-10	Jan-95	19.3	5.2	155	-189	0.2	0.08	0.08	1.4	28.2	2	1.29	12	260	14.2	6.1
MW-11	Jan-95	20.5	5.8	249	-223	0.2	0.08	1.27	27	7.74	1	3.02	76	380	19.3	8
	Feb-99	18.3	6.2	340	-21	0.4	< 0.1	1.35	50	14.4	0.5	0.191	100	160	21.5	6.99
MW-49	Jan-95	16.6	5.6	147	-176	0.1	<.05	<.05	2.2	7.27	NA	0.2	34	160	15	5.1
MW-50	Jan-95	17.8	5.8	196	-160	0.2	<.05	<.05	1.2	2.5	0.1	0.232	46	180	27.8	3.2
MP-8S	Jan-95	17.9	5.7	147	-200	0.3	<.05	0.16	11	4.19	0.1	4.73	60	NA	17.2	6
	Feb-99	15.9	6.1	175	42	0.7	< 0.1	< 0.1	NA	< 0.5	NA	1.86	NA	NA	14.9	7.01
MP-10S	Jan-95	17.3	5.6	159	-206	0.2	<.05	0.07	8.5	4.11	2	2.10	36	320	24.3	9.7
	Feb-99	16.8	6.5	240	-1	3.2	< 0.1	<0.1	4	2.55	0.1	NA	100	60	7.18	5.14
MP-12D	Jan-95	19.3	6.9	401	-90	0.3	<.05	<.05	1	<.5	<.1	1.16	160	120	22.2	2.2
	Feb-99	18.8	7.1	514	1	0.1	< 0.1	0.26	0.6	< 0.5	0.2	0.373	200	45	25.5	1.9
MP-15S	Jan-95	17.6	5.5	165	-190	0.2	<.05	<.05	2.5	9.02	0.7	0.766	16	220	30.2	3.6
MP-16S	Jan-95	17.9	5.7	81	-204	0.4	<.05	<.05	1.3	2.32	0.1	0.037	39	160	6.89	1.9
	Feb-99	16.8	5.8	70	66	0.9	< 0.1	< 0.1	0.8	2.92	0.1	0.009	20	40	5.03	1.12
MP-17S	Jan-95	20.2	5.6	89	-70	0.2	0.14	<.05	2.3	10	NA	NA	25	NA	8.63	0.8
	Feb-99	18.2	5.7	150	114	0.4	< 0.1	< 0.1	0.9	7.86	0.9	0.014	20	50	9.54	1.51
MP-18M	Jan-95	17.5	7.4	501	NA	NA	<.05	0.19	<.05	<.5	NA	1.87	226	NA	17.3	5.4

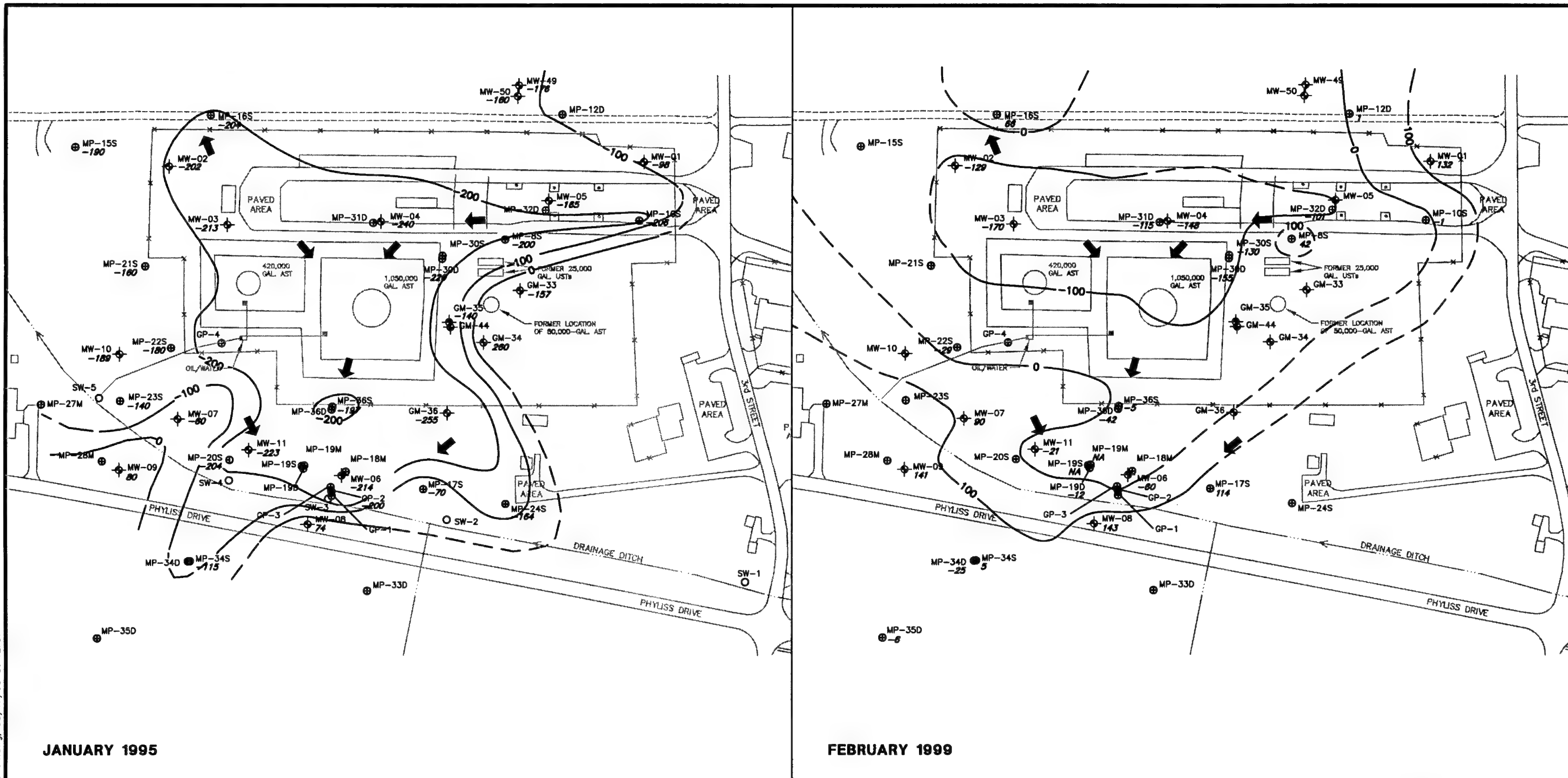
TABLE 5 (Continued)
GROUNDWATER GEOCHEMICAL DATA
POL BULK FUEL STORAGE AREA
INTRINSIC REMEDIATION CAS ADDENDUM
MYRTLE BEACH AFB, SOUTH CAROLINA

Sample Location	Sample Date	Water Temp. (°C)[a/]	pH (su)[b/]	Conductivity (µmhos/cm)[c/]	Redox Potential (mV)[d/]	Dissolved Oxygen (mg/L)[e/]	Nitrate + Nitrite (mg/L)	Ammonia (mg/L)	Ferrous Iron (mg/L)	Sulfate (mg/L)	Sulfide (mg/L)	Methane (mg/L)	Total Alkanity (mg/L)	Carbon Dioxide (mg/L)	Chloride (mg/L)	Total Organic Carbon (mg/L)
MP-19S	Jan-95	17.9	5.6	110	NA	1.6	<.05	<.05	15	<.5	NA	5.36	27	NA	11.2	9.2
	Feb-99	NA	NA	NA	NA	NA	< 0.1	< 0.1	10	< 0.5	2	0.183	60	120	10	9.02
MP-19M	Jan-95	NA	7.1	535	NA	NA	<.05	0.12	0.1	<.5	NA	1.47	248	NA	17.8	7.2
MP-19D	Jan-95	18.9	7.2	528	-150	0.2	<.05	0.1	0.4	<.5	<.1	1.75	204	104	38.3	4
	Feb-99	18.8	7.2	530	-12	0.1	< 0.1	0.18	0.3	< 0.5	< 0.1	0.368	220	45	38.3	2.77
MP-20S	Jan-95	20.1	5.6	165	-204	0.5	<.05	<.05	2	6.44	<.1	0.295	62	338	11.4	9.2
MP-21S	Jan-95	17.1	5.6	59	-160	0.7	<.05	<.05	0.5	6.51	<.1	0.305	29	100	5.02	1.5
MP-22S	Jan-95	17	5.6	53	-180	0.6	<.05	<.05	1.1	4.27	0.1	0.4	15	90	5.46	2.1
	Feb-99	16.5	5.6	44	-29	0.3	< 0.1	< 0.1	0.8	2.72	1.0	0.106	20	60	4.56	2.11
MP-23S	Jan-95	19.1	7.3	337	-140	0.5	<.05	0.06	0.3	4.41	<.1	0.183	134	58	15.5	3.1
MP-24S	Jan-95	19.8	5.2	319	-164	0.1	<.05	<.05	1.7	61.5	<.1	0.001	9	184	41.6	2.4
MP-27M	Jan-95	NA	7.2	514	-100	NA	<.05	<.05	2	8.67	<.1	0.162	241	92	13.4	2.3
MP-28M	Jan-95	NA	7.5	517	-92	NA	<.05	<.05	0.3	7.84	<.1	0.208	217	84	29.9	1.6
MP-30S	Jan-95	17.5	6.3	308	-220	0.3	<.05	0.31	23	<.5	0.1	17.1	145	400	9.58	18.1
	Feb-99	16.3	6.2	393	-130	0.2	< 0.1	< 0.1	20	< 0.5	0.5	27.7	120	200	4.67	15.6
MP-30D	Jan-95	20.6	7.3	425	-120	0.1	<.05	<.06	1	<.5	<.1	1.23	173	130	21.6	8.4
	Feb-99	19.1	6.9	490	-155	0.2	< 0.1	0.22	1.2	< 0.5	0.1	4.03	240	55	12	3.17
MP-31D	Jan-95	20.5	7.2	433	-130	0.1	<.05	0.11	0.7	<.5	<.1	1.41	180	124	23.4	2.0
	Feb-99	20.3	7	488	-115	0.6	< 0.1	0.55	0.8	< 0.5	< 0.1	2.71	220	45	22.5	2.37
MP-32D	Jan-95	19.4	7	597	-172	0.5	<.05	0.08	1.2	79.7	<.1	0.744	173	95	24.1	5.3
	Feb-99	20.1	7.1	462	-101	0.2	< 0.1	0.22	0.6	2.10	0.1	1.75	180	30	24.4	2.14
MP-33D	Jan-95	18.2	7.3	599	-140	0.2	<.05	<.05	1.7	<.5	<.1	0.22	208	100	54.5	1.8
MP-34S	Jan-95	18.3	6.8	1410	-115	0.1	<.05	<.05	15	84.1	<.1	NA	570	500	60.9	4.6
	Feb-99	17.5	6.8	1100	5	0.3	< 0.1	< 0.1	20	33	< 0.1	0.406	> 2000	> 200	23.2	9.55
MP-34D	Jan-95	18.1	7.4	447	-178	0.1	<.05	<.05	1	8.03	<.1	0.141	165	108	26.5	1.4
	Feb-99	18.3	7.2	458	-25	0.4	< 0.1	< 0.1	2	10.8	< 0.1	0.112	240	20	17.2	1.54
MP-35D	Jan-95	18.3	7.5	450	-180	0.2	<.05	<.05	0.3	3.85	NA	0.137	184	138	22.7	1.1
	Feb-99	18.8	7.3	497	-6	0.1	< 0.1	< 0.1	0.8	3.67	0.1	0.185	220	100	27.6	1.93
MP-36S	Jan-95	16.3	5.6	67	-197	0.2	<.05	<.05	6.3	1.91	1	1.34	20	186	6.34	13.4
	Feb-99	15.1	5.7	58	-5	1	< 0.1	< 0.1	2	4.79	0.5	0.908	40	35	7.85	3.72
MP-36D	Jan-95	18.8	7.3	490	-97	0.2	0.09	<.05	3	<.5	<.1	0.461	196	172	37.9	3.0
	Feb-99	17.9	7.2	410	-42	0	< 0.1	< 0.1	1.5	< 0.5	< 0.1	0.516	180	30	41.4	2.79
GP1S	Jan-95	17.3	NA	NA	NA	0.3	<.05	<.05	NA	NA	NA	NA	NA	NA	NA	NA
GP1D	Jan-95	16.6	5.9	160	-205	0.7	<.05	<.05	0.7	<.5	0.1	9.12	63	180	9.4	5.1

TABLE 5 (Continued)
GROUNDWATER GEOCHEMICAL DATA
POL BULK FUEL STORAGE AREA
INTRINSIC REMEDIATION CAS ADDENDUM
MYRTLE BEACH AFB, SOUTH CAROLINA

Sample Location	Sample Date	Water Temp. (°C)[a]	pH (su)[b]	Conductivity (µmhos/cm)[c]	Redox Potential (mV)[d]	Dissolved Oxygen (mg/L)[e]	Nitrate + Nitrite (mg/L)	Ammonia (mg/L)	Ferrous Iron (mg/L)	Sulfate (mg/L)	Sulfide (mg/L)	Methane (mg/L)	Total Alkanity (mg/L)	Carbon Dioxide (mg/L)	Chloride (mg/L)	Total Organic Carbon (mg/L)
GP2S	Jan-95	17.3	5.7	160	-200	0.4	<.05	0.07	20	<.5	0.7	9.22	70	NA	8.83	10.7
GP3D	Jan-95	19.2	5.9	172	-164	0.2	0.07	<.05	1.1	<.5	0.1	NA	72	282	9.63	7.0
GP3S	Jan-95	20.5	NA	NA	NA	0.9	0.15	3.15	NA	NA	NA	NA	NA	NA	NA	NA
GM-33	Jan-95	17.1	5.4	47	157	1.9	0.11	<.05	<.05	5.58	NA	0.002	8	76	4.21	4.2
GM-34	Jan-95	17.1	5.5	81	260	0.6	0.08	<.05	0.2	11.4	NA	0.093	3	120	9.05	1.6
GM-35	Jan-95	18.1	6	103	-140	0.1	0.08	0.06	3.8	3.18	0.5	1.50	34	118	5.1	15.8
GM-36	Jan-95	16.6	5.9	216	-255	<0.1	0.08	0.88	19.3	5.57	2	1.33	72	320	18.7	6.2
GM-44	Jan-95	19.2	6.9	436	-50	0.1	0.11	0.2	0.5	<.5	<.1	1.19	204	142	19.9	1.6

[a] °C = degrees Celcius.
[b] su = standard pH units.
[c] µmhos/cm = micromhos per centimeter
[d] mV = millivolts
[e] mg/L = milligrams per liter
[f] NA = Sample not analyzed for this parameter



LEGEND

MW-02 −202	MONITORING WELL WITH REDOX POTENTIAL (mV)
MP-15S −190	MONITORING POINT WITH REDOX POTENTIAL (mV)
SW-1	SURFACE WATER SAMPLING LOCATION (1995)
—100—	LINE OF EQUAL REDOX POTENTIAL (mV) (DASHED WHERE INFERRED) CONTOUR INTERVAL = 100 mV
(arrow)	APPROXIMATE DIRECTION OF GROUNDWATER FLOW
NA	NOT AVAILABLE

0 90 180 360
FEET

FIGURE 9

REDOX IN GROUNDWATER

POL Bulk Fuel Storage Area
Addendum
Myrtle Beach AFB, South Carolina

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groundwater through precipitation. Low concentrations of DO across the site suggest that anaerobic conditions dominate in groundwater and aerobic respiration is limited. However, notable increases in DO from 1995 to 1999 were measured at MW-01 (1.2 mg/L to 1.8 mg/L), MW-09 (0.2 mg/L to 2.5 mg/L), and MP-10S (0.2 mg/L to 3.2 mg/L). Well locations MW-01 and MP-10S are located at the upgradient edge of the BTEX plume, and MW-09 is located on the downgradient perimeter of the plume. Therefore, aerobic respiration may be significant at localized areas on the periphery of the BTEX plume.

Nitrate + Nitrite

Nitrate + nitrite concentrations measured during the February 1999 sampling event were below detection limits in 21 of the 25 wells sampled and analyzed for nitrate/nitrite (Table 5). February 1999 results are similar to results in January 1995. Due to the general lack of nitrate/nitrite in groundwater at the site, nitrate is not considered to be an important electron acceptor.

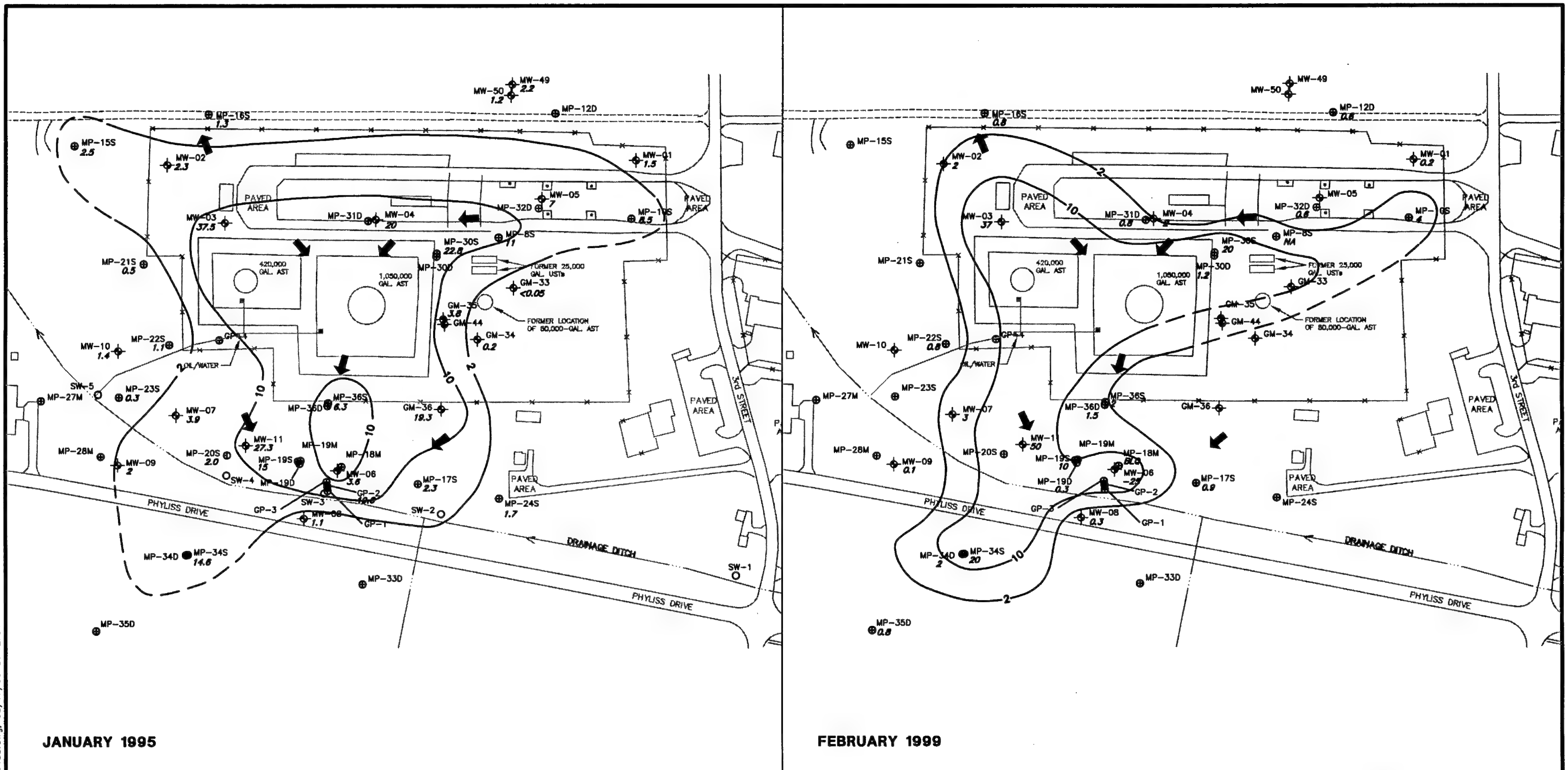
Ferrous Iron

Ferrous iron (Fe^{2+}) is a byproduct of the anaerobic biodegradation process of ferric iron (Fe^{3+}) reduction. Accumulation of ferrous iron in groundwater indicates that this microbially assisted process is or has occurred recently. Ferrous iron concentrations were measured at the site are presented in Table 5. Ferrous iron concentration contour maps for January 1995 and February 1999 are shown on Figure 10. Comparison of Figures 3 and 10 shows that areas with elevated total BTEX concentrations also have increased concentrations of ferrous iron. Concentrations of ferrous iron measured at the site during February 1999 range from 0.1 mg/L to 50 mg/L. Ferrous iron concentrations from 1995 to 1999 are similar, with notable increases at monitoring wells MW-06 (3.6 mg/L to 25 mg/L), MW-11 (27 mg/L to 50 mg/L), and MP-34S (14.6 to 20 mg/L). These wells are located at the toe of the BTEX plume, where an increase in BTEX concentrations in 1999 was observed. This suggests that the area of iron reduction has expanded along with increasing BTEX concentrations.

Recent evidence suggests that the reduction of ferric iron to ferrous iron cannot proceed without microbial mediation (Lovley and Phillips, 1988; Lovley *et al.*, 1991; Chapelle, 1993); therefore, presence of ferrous iron strongly suggests that ferric iron is being used as an electron acceptor at the site. Furthermore, the coincident ferrous iron and BTEX plumes indicate that the reduction of ferric iron to ferrous iron is occurring during biodegradation of BTEX compounds.

Sulfate

Sulfate concentrations were measured at 25 of the 28 wells sampled during February 1999 and are presented in Table 5. Concentrations of sulfate measured at the site during February 1999 range from <0.5 mg/L to 33 mg/L. Sulfate concentration contour maps for January 1995 and February 1999 are shown on Figure 11. Comparison of Figures 3 and 11 shows that the areas with the highest total BTEX concentrations have depleted sulfate concentrations. The correlation of depleted sulfate concentrations with the highest BTEX concentrations provides strong evidence that



LEGEND

MW-02 2.3 — MONITORING WELL FERROUS IRON CONCENTRATION (mg/L)

MP-15S 2.5 — MONITORING POINT FERROUS IRON CONCENTRATION (mg/L)

SW-1 — SURFACE WATER SAMPLING LOCATION (1995)

APPROXIMATE DIRECTION OF GROUNDWATER FLOW

—2— LINE OF EQUAL FERROUS IRON CONCENTRATION (mg/L) (DASHED WHERE INFERRED) CONTOUR INTERVAL = VARIABLE

NOTE: CONTOURED ON THE BASIS OF THE CONCENTRATIONS DETECTED IN SHALLOW GROUNDWATER SAMPLES

0 90 180 360
FEET

FIGURE 10

FERROUS IRON ISOPLETH MAP FOR SHALLOW GROUNDWATER

POL Bulk Fuel Storage Area
Intrinsic Remediation CAS Addendum
Myrtle Beach AFB, South Carolina

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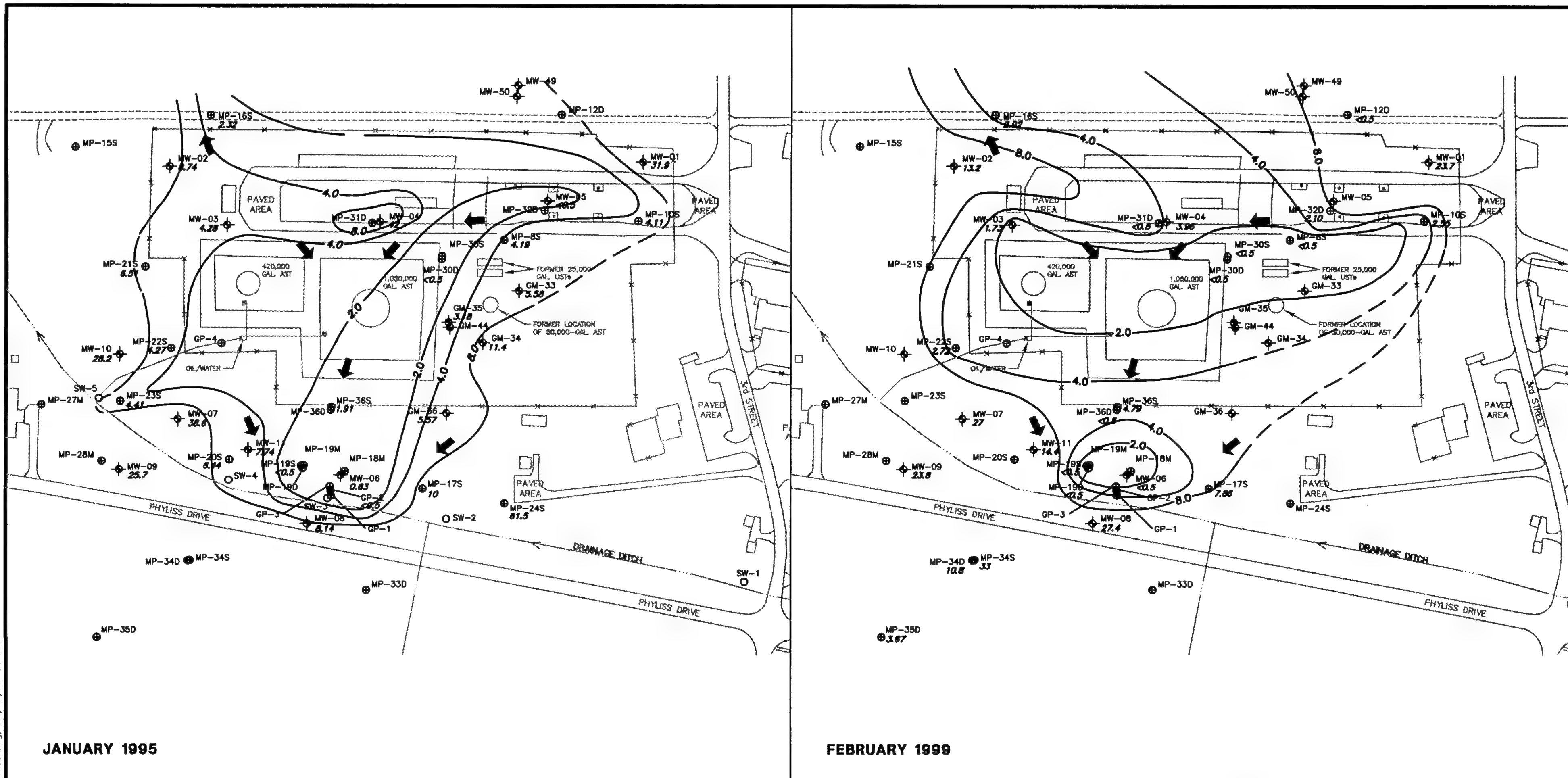

LEGEND

MW-02 8.74 — MONITORING WELL WITH SULFATE CONCENTRATION (mg/L)

MP-15S 2.32 — MONITORING POINT WITH SULFATGE CONCENTRATION (mg/L)

SW-1 — SURFACE WATER SAMPLING LOCATION (1995)

APPROXIMATE DIRECTION OF GROUNDWATER FLOW

—4.0— LINE OF EQUAL SULFATE CONCENTRATION (mg/L) (DASHED WHERE INFERRED) CONTOUR INTERVAL = VARIABLE

NOTE: CONTOURED ON THE BASIS OF THE CONCENTRATIONS DETECTED IN SHALLOW GROUNDWATER SAMPLES

0 90 180 360

FEET

FIGURE 11

SULFATE ISOPLETH MAP FOR SHALLOW GROUNDWATER

POL Bulk Fuel Storage Area
Intrinsic Remediation CAS Addendum
Myrtle Beach AFB, South Carolina

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anaerobic biodegradation of the BTEX compounds is occurring at the site through the microbially mediated process of sulfate reduction.

Since January 1995, the area of depleted sulfate concentrations has remained stable. Concentrations of sulfate decreased from 1995 to 1999 at 12 locations, increased at six locations, and remained below detection at seven locations. Notable decreases in sulfate concentrations occurred within the BTEX plume source are at wells MW-04 (42 mg/L to 3.96 mg/L) and MP-8S (4.19 mg/L to less than 0.5 mg/L). Notable decreases in sulfate concentrations also were observed at the toe of the BTEX plume at wells MP-34S (84.1 mg/L to 33 mg/L) and MP-34D (79.7 mg/L to 2.1 mg/L). The decrease in sulfate concentrations at the toe of the BTEX plume corresponds to an increase in BTEX concentrations. The decrease in sulfate concentrations at these locations suggests that sulfate reduction has continued at the site in the source area, and has expanded along with increasing BTEX concentrations at the toe of the plume.

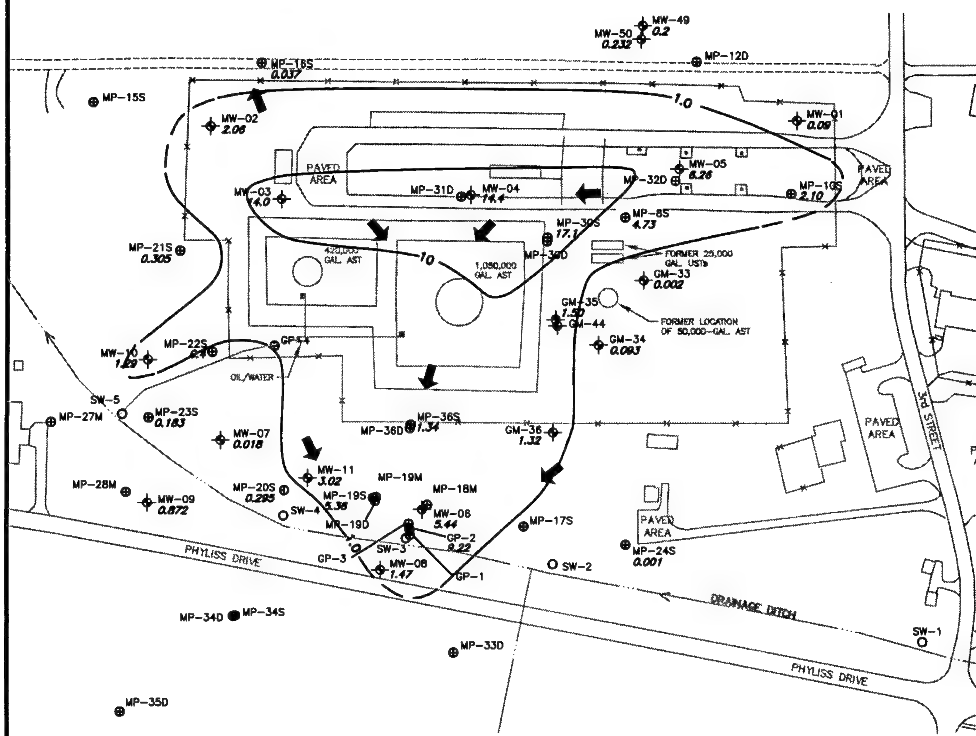
Methane

During methanogenesis, an anaerobic biodegradation process, CO_2 (or acetate) is used as an electron acceptor and methane is produced. The presence of methane in groundwater is indicative of strongly reducing conditions and microbial degradation of fuel hydrocarbons. Methane concentrations in groundwater are included in Table 5, and methane concentration isopleth maps for January 1995 and February 1999 are presented on Figure 12. Comparison of Figures 3 and 12 shows that the areas with the highest total BTEX concentrations have elevated methane concentrations. The correlation of elevated methane concentrations with the highest BTEX concentrations provides strong evidence that anaerobic biodegradation of the BTEX compounds is occurring at the site through the microbially mediated process of methanogenesis.

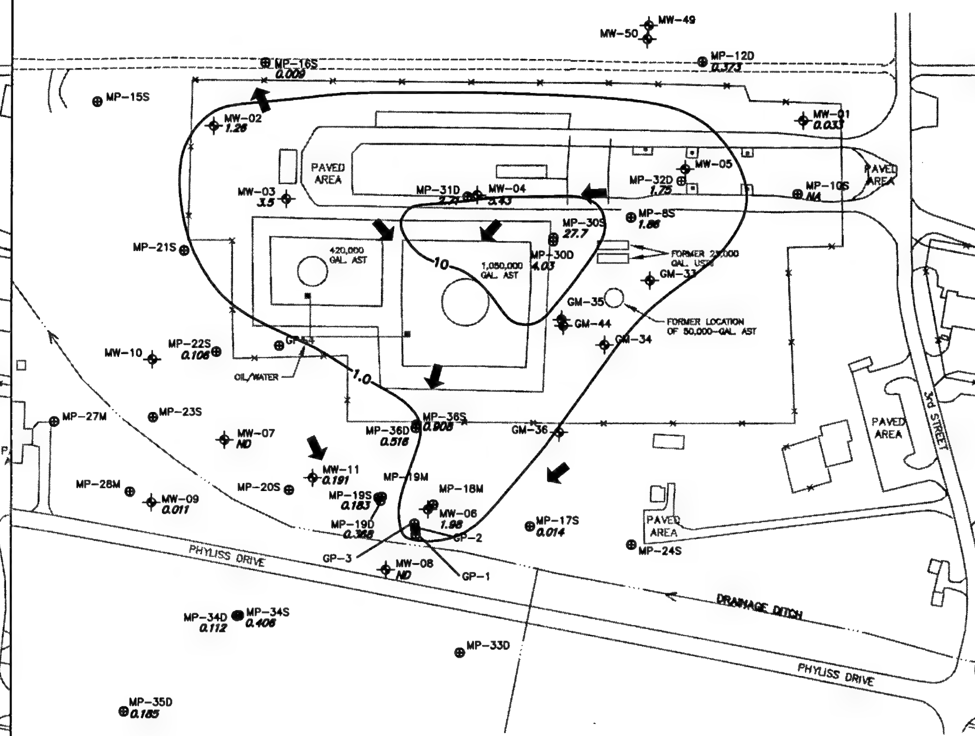
From January 1995 to February 1999, the area of elevated methane concentrations has remained stable. Methane concentrations have generally decreased in the shallow and intermediate portions of the plume (Table 5, Figure 12). In contrast, methane concentrations increased at shallow well location MP-30S, and in deeper portions of the BTEX plume at well locations MP-30D, MP-31D, MP-32D, MP-35D, and MP-36D. This suggests that methanogenesis continues to occur in the deeper intervals of the BTEX plume. Methanogenesis in the shallow portions of the BTEX plume may be limited by less anaerobic conditions as a result of recharge of oxygenated water from infiltration or upgradient flow.

Alkalinity

Alkalinity is a measure of the ability of water to buffer changes in pH. Alkalinity can be used as an indicator of biodegradation of BTEX. Biodegradation of BTEX produces carbon dioxide which, when mixed with water in the proper conditions, produces carbonic acid. In aquifers that have carbonate minerals as part of the matrix, carbonic acid dissolves these minerals, increasing the alkalinity of the groundwater. Therefore, an increase in alkalinity can be observed in areas of active intrinsic bioremediation of BTEX. Total alkalinity [measured as calcium carbonate ($CaCO_3$)] of groundwater samples collected at the site from in January 1995 and February 1999 is summarized in Table 5.



JANUARY 1995



FEBRUARY 1999

LEGEND

MW-02 2.06 — MONITORING WELL WITH METHANE CONCENTRATION (mg/L)

MP-15S 0.037 — MONITORING POINT WITH METHANE CONCENTRATION (mg/L)

SW-1 — SURFACE WATER SAMPLING LOCATION (1995)

APPROXIMATE DIRECTION OF GROUNDWATER FLOW

—1.0— LINE OF EQUAL METHANE CONCENTRATION (mg/L) (DASHED WHERE INFERRED) CONTOUR INTERVAL = VARIABLE

NOTE: CONTOURED ON THE BASIS OF THE CONCENTRATIONS DETECTED IN SHALLOW GROUNDWATER SAMPLES

0 90 180 360
FEET

FIGURE 12

METHANE ISOPLETH MAP FOR SHALLOW GROUNDWATER

POL Bulk Fuel Storage Area
Intrinsic Remediation CAS Addendum
Myrtle Beach AFB, South Carolina

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Of the wells with available alkalinity data for both January 1995 and February 1999, alkalinity increased in 19 locations and decreased in six locations. Therefore, alkalinity data support the continued occurrence of BTEX biodegradation at the site. A notable increase was observed at well location MP-34S where alkalinity increased from 570 mg/L to greater than 2,000 mg/L. The increase in alkalinity corresponds to an increase in ferrous iron, a decrease in sulfate, and an increase in BTEX concentration. This suggests increased microbial activity at this location in response to an increase in BTEX concentration.

3.0 SUMMARY AND CONCLUSIONS

Without remediation of the source (i.e., mobile and residual phase LNAPL) natural attenuation is the only process acting to control the BTEX groundwater plume at the POL Yard. BTEX concentrations at downgradient well locations MW-08, MW-09, MP-17S, and MP-35D decreased from low levels in 1995 to below detection in 1999. However, BTEX concentrations at downgradient location MP-34S/MP-34D increased significantly. Therefore, the toe of the BTEX plume has migrated beneath the southern ditch and Phyliss Drive in the vicinity of monitoring point pair MP-34S and MP-34D. BTEX concentrations were also observed to increase in deeper intervals of the plume at well locations MP-19M, MP-19D, MP-30D, MP-31D, MP-34D, and MP-36D.

Geochemical indicators continue to support the occurrence of intrinsic bioremediation at the site as evidenced by the distributions of electron acceptors/metabolic byproducts that are involved in biologically mediated redox reactions. The BTEX plume is still largely anaerobic, and anaerobic biodegradation processes (e.g., iron reduction, sulfate reduction, methanogenesis) appear to be the predominant destructive attenuation mechanisms. The February 1999 DO and ORP measurements suggest the presence of a more oxidizing groundwater environment, suggesting that the processes of sulfate reduction and methanogenesis, which both require a highly reducing environment, were less predominant in February 1999 than in January 1995. However, additional ORP data is required to assess whether this is a long-term trend, representative of natural variability, or due to sensitivity of sampling protocols or techniques.

An increase in BTEX concentrations in the downgradient toe and deeper portions of the plume appear to be offset by increasing microbial activity at those locations as evidenced by increasing ferrous iron concentrations, decreasing sulfate concentrations, and increasing methane concentrations. BTEX concentrations near the source area (MW-04 and MP-30S) appear to be decreasing, and this decrease may eventually cause the plume extent to diminish. Continued long-term monitoring is recommended to monitor the evolution of the plume and to continue to evaluate the appropriateness of source reduction activities.

4.0 REFERENCES

Bouwer, E.J., 1992, Bioremediation of Subsurface Contaminants, In R. Mitchell, editor, Environmental Microbiology, Wiley-Liss, New York, New York.

Chapelle, F.H., 1993, Ground-water Microbiology and Geochemistry. John Wiley and Sons, Inc., New York, NY.

Cozzarelli, I.M., Eganhouse, R.P., and Baedecker, M.J., 1990, Transformation of Monoaromatic Hydrocarbons to Organic Acids in Anoxic Ground Water Environment. Environmental and Geological Water Science, 16.

Engineering-Science, Inc. (ES), 1981, *Installation Restoration Program, Phase I - Records Search, Hazardous Materials Disposal Sites, Myrtle Beach AFB, South Carolina*. October.

Lovley, D.R., and Phillips, E.J.P., 1988, Novel mode of microbial energy metabolism: organic carbon oxidation coupled to dissimilatory reduction of iron or manganese: Applied and Environmental Microbiology, v. 54, no. 6, p. 1472 - 1480.

Lovley, D.R., Phillips, E.J.P., and Lonergan, D.J., 1991, Enzymatic versus nonenzymatic mechanisms for Fe(III) reduction in aquatic sediments: Environmental Science and Technology, v. 26, no. 6, p. 1062 - 1067.

Parsons Engineering Science, Inc. (Parsons ES), 1997, Corrective Action Study to Evaluate Intrinsic Remediation for the POL Bulk Fuel Storage Area, Myrtle Beach Air Force Base, Myrtle Beach, South Carolina. Prepared for Air Force Center for Environmental Excellence, Technology Transfer Division, Brooks AFB, Texas, US Air Force Contract F41624-92-D-8036, May.

US Geological Survey (USGS), 1994, 7.5 Minute Quadrangle Map of Myrtle Beach, South Carolina.

Wilson, B.H., Wilson, J.T., Kampbell, D.H., Bledsoe, B.E., and Armstrong, J.M., 1990, Biotransformation of Monoaromatic and Chlorinated Hydrocarbons at an Aviation Gasoline Spill Site. Geomicrobiology Journal, 8:225-240.

ATTACHMENT A

ANALYTICAL RESULTS
FEBRUARY 1999

MANTECH

Myrtle Beach POL Yard
Update 729691.22100

Ref: 99-MB7
Contract #68-C-98-138
March 8, 1999

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection and Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: Dr. D. Fine DFine

Dear Don:

Please find attached the analytical results for Service Request # SF-0-50 requesting the analysis of aqueous samples from Myrtle Beach AFB, SC to be analyzed for BTEXXX, TMB's and MTBE. The 28 samples plus duplicates were received in capped, 40 mL VOA vials on February 24, 1999. The samples were analyzed on March 2 through March 5, 1999. All samples were acquired using the Millennium data system. A 5 point (1-1000 ppb) external calibration curve was used to determine the concentration for all compounds. Samples MW-6, MP-8S, MP-19S, MP-30S and MP-36S were diluted 1:10 with boiled milli-Q water.

RSKSOP-122 "Analysis of Volatile Aromatic Hydrocarbons with Separation of Xylene Isomers by Purge & Trap Gas Chromatography" was used for these analyses. Auto-sampling was performed using a Dynatech Precision autosampler system in line with a Tekmar LSC 2000 concentrator.

Sincerely,

Mark Blankenship

Mark Blankenship

xc: R.L. Cosby
J.L. Seeley MGL for JLS
G.B. Smith

SAMPLE NAME	MTBE	BENZENE	TOLUENE	ETHYLBENZENE	p-XYLENE	m-XYLENE	o-XYLENE	1,3,5-TMB	1,2,4-TMB	1,2,3-TMB
1 PPM STD	1.2	1.1	1.0	1.1	1.0	1.0	0.9	1.0	0.9	0.9
) PPB QA\QC	21.4	21.0	20.7	21.1	21.2	21.3	20.6	23.0	22.0	19.2
W-1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
W-2	1.3	178	BLQ	2.5	1.6	1.8	BLQ	ND	BLQ	BLQ
W-3	BLQ	9.0	BLQ	BLQ	ND	ND	ND	ND	BLQ	ND
W-4	BLQ	294	114	268	391	939	159	157	340	174
W-6	28.0	271	18.7	778	891	2580	269	260	645	278
W-7	ND	BLQ	ND	38.4	69.6	37.6	ND	BLQ	BLQ	BLQ
W-8	ND	BLQ	ND	ND	BLQ	BLQ	ND	ND	ND	ND
W-9	ND	BLQ	ND	ND	ND	BLQ	ND	ND	ND	ND
) PPB STD	10.7	9.7	9.6	10.5	10.0	10.0	9.6	10.4	10.0	9.8
W-11	BLQ	27.3	1.3	1.8	21.1	45.3	35.4	1.1	4.7	2.7
P-8S	57.7	950	662	366	410	1070	348	173	557	258
P-16S	ND	BLQ	BLQ	ND	ND	BLQ	ND	ND	ND	ND
P-16S LAB DUPLICATE	ND	BLQ	BLQ	ND	ND	BLQ	ND	ND	ND	ND
P-17S	ND	BLQ	ND	ND	ND	BLQ	ND	ND	ND	ND
P-19S	31.4	592	80.1	629	673	2090	500	172	454	204
P-22S	ND	BLQ	ND	ND	1.2	ND	BLQ	ND	2.9	BLQ
P-30S	29.5	288	14.4	605	664	1360	BLQ	129	392	367
P-34S	ND	3.4	ND	47.5	86.7	108	ND	ND	BLQ	BLQ
P-36S	22.4	1089	401	1480	1310	3440	2080	363	913	396
)0 PPB STD	443	483	481	476	476	476	481	480	494	494
C LAB BLANK	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
P-10	2.7	23.9	2.9	62.5	104	156	1.3	6.2	21.1	15.6
P-12D	ND	BLQ	BLQ	1.9	3.8	2.6	BLQ	ND	ND	ND
P-19D	ND	3.0	BLQ	BLQ	3.1	8.4	ND	BLQ	2.1	1.0
P-19D LAB DUPLICATE	ND	2.8	BLQ	BLQ	3.0	7.7	ND	BLQ	1.9	1.3
P-30D	20.3	291	BLQ	7.4	26.8	12.2	BLQ	2.0	9.5	14.4
P-31D	ND	44.3	BLQ	1.8	1.5	2.7	BLQ	BLQ	1.4	1.2
P-32D	ND	BLQ	BLQ	ND	ND	BLQ	ND	ND	ND	ND
P-34D	ND	31.4	ND	ND	ND	ND	ND	ND	ND	ND
P-35D	ND	BLQ	BLQ	BLQ	BLQ	BLQ	ND	ND	ND	ND
P-36D	ND	2.8	1.2	9.3	9.9	30.4	8.5	1.7	8.1	2.6
P-18M	BLQ	BLQ	1.7	BLQ	BLQ	1.2	BLQ	ND	BLQ	BLQ
P-19M	BLQ	99.7	17.5	102.5	99.0	317	101	14.4	41.8	22.7
PB STD	1.1	1.0	0.9	1.0	1.0	1.0	0.9	0.8	0.9	0.8

ND = None Detected; BLQ = Below Limit of Quantitation, 1 ppb.

Analyzed 3/2/99 thru 3/5/99

MANTECH

MEMORANDUM
MANTECH ENVIRONMENTAL RESEARCH SERVICES CORP.
Environmental Science

In reply refer to: 99-AZ10
68-C-98-138

To: Dr. Don Kampbell

Thru: Dennis Fine D. Fine

From: Amy Zhao
A.Z.

Subject: SF-0-50

Date: March 9, 1999

Copies: R.L. Cosby
G.B. Smith
J.L. Seeley

As requested in Service Request #SF-0-50, gas analysis was performed for methane, ethylene and ethane from Myrtle Beach AFB. The samples were received on February 24, 1999, and analyzed on March 2, 1999. Calculations were done as per RSKSOP-175. Analyses were performed as per RSKSOP-194.

If you have any questions concerning this data, please feel free to contact me.

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Center, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 580-436-8660 FAX 580-436-8501

Printed 03/09/99 SF-0-50 | Originator: Don Kampbell | Site:Myrtle Beach AFB

Analyst: A. Zhao

Sample Received 02/24/99 | Sample Analyzed 03/02/99

Sample	Methane ppm (Gas)	Methane ppm mg/L(Water)	Ethylene ppm (Gas)	Ethylene ppm mg/L(Water)	Ethane ppm (Gas)	Ethane ppm (Water)
100 ppm CH4	1.00E+02	~	**	~	**	~
100 ppm C2H4	**	~	9.64E+01	~	**	~
100 ppm C2H6	**	~	**	~	9.34E+01	~
HP. Helium Blank	~	**	~	**	~	**
Lab Blank	~	**	~	**	~	**
MW-1(2-18)	~	0.033	~	**	~	**
MW-2(2-18)	~	1.26	~	**	~	**
MW-3(2-18)	~	3.50	~	**	~	**
MW-4(2-18)	~	5.43	~	**	~	**
MW-6(2-19)	~	1.98	~	**	~	**
MW-6 Lab Dup(2-19)	~	2.00	~	**	~	**
MW-7(2-19)	~	**	~	**	~	**
MW-8(2-19)	~	**	~	**	~	**
MW-8S(2-20)	~	1.86	~	**	~	**
MW-9(2-19)	~	0.011	~	**	~	**
MW-9 Field Dup(2-19)	~	0.010	~	**	~	**
MW-10 (2-18)	~	0.821	~	**	~	**
10,000 PPM CH4	9.44E+04	~	**	~	**	~
MP-11 (2-19)	~	0.191	~	**	~	**
MP-12D (2-20)	~	0.373	~	**	~	**
MP-16S (2-20)	~	0.009	~	**	~	**
MP-17S (2-19)	~	0.014	~	**	~	**
MP-19D (2-19)	~	0.368	~	**	~	**
MP-19D Lab Dup (2-19)	~	0.366	~	**	~	**
MP-19S (2-19)	~	0.183	~	**	~	**
MP-22S (2-19)	~	0.106	~	**	~	**
MP-30D (2-18)	~	4.03	~	**	~	**
MP-30S (2-18)	~	27.7	~	**	~	**
MP-31D (2-18)	~	2.71	~	**	~	**
MP-31D Field Dup(2-18)	~	2.65	~	**	~	**
1000 PPM CH4	1.05E+03	~	**	~	**	~
MP-32D (2-18)	~	1.75	~	**	~	**
MP-34D (2-20)	~	0.112	~	**	~	**
MP-34S (2-20)	~	0.406	~	**	~	**
MP-35D (2-20)	~	0.185	~	**	~	**
MP-36D (2-19)	~	0.516	~	**	~	**
MP--36D Lab Dup (2-19)	~	0.510	~	**	~	**
MP-36S (2-19)	~	0.908	~	**	~	**
MP-36S Field Dup (2-19)	~	0.908	~	**	~	**
10 PPM CH4	1.00E+01	~	**	~	**	~
10 PPM C2H4	**	~	9.70E+00	~	**	~
10 PPM C2H6	**	~	**	~	9.80E+00	~
Lower Limit of Quantitation	10.0	0.001	10.0	0.003	10.0	0.002

Units for the samples are mg/L dissolved in water.
Units for the standards are parts per million.

sample date is represented in ( ) , 1999.
** denotes None Detected.
* denotes Below Limit of Quantitation.
~ denotes Not Applicable.

MEMORANDUM
MANTECH ENVIRONMENTAL RESEARCH SERVICES CORP
Environmental Science

In reply refer to : 98-SH12
Contract #68-C-98-138

To: Dr. Don Kampbell

From: Sharon Hightower

Thru: Dennis Fine

Subject: [redacted] Date: February 26, 1999

Copies: R.L. Cosby
G.B. Smith
J.L. Seeley
L.K. Pennington

Attached are TOC results for 24 Myrtle Beach samples submitted February 23, 1999 under Service Request #SF-0-50. Sample analysis was begun February 25, 1999 and completed February 25, 1999 using RSKSOP-102.

Blanks, duplicates, and AQC samples were analyzed along with your samples, as appropriate, for quality control. If you have any questions concerning this data, please feel free to ask me.

ManTech Environmental Research Services Corporation
R.S. Kerr Environmental Research Center, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 580-436-8660 FAX 580-436-8501

KAMPBELL MYRTLE BEACH LIQUIDS SF-0-50
SAMPLES RECEIVED 2/23/99
SAMPLES ANALYZED 2/25/99 BY SHARON HIGHTOWER

SAMPLE	MG/L TOC
MP-10, 2/18	5.14
MP-12D, 2/20	1.90
MP-19D, 2/19	2.77
MP-30D, 2/19	3.17
MP-31D, 2/18	2.37
MP-32D, 2/20	2.14
MP-34D, 2/20	1.54
MP-35D, 2/20	1.93
MP-36D, 2/20	2.79
MP-8S, 2/20	7.01
DUP	7.09
WP39	70.1
MP-16S, 2/20	1.12
MP-17S, 2/19	1.51
MP-19S, 2/19	9.02
MP-22S, 2/19	2.11
MP-30S, 2/18	15.6
MP-34S, 2/20	9.55
MP-36S, 2/19	3.72
MW-1, 2/18	8.00
MW-2, 2/18	5.34
MW-3, 2/18	14.1
DUP	14.1
WP39	73.3
5 MG/L	4.87
MW-4, 2/18	10.1
MW-06, 2/19	7.94
MW-07, 2/19	6.34
MW-08, 2/19	4.03
MW-09, 2/19	5.96
MW-11, 2/19	6.99
5 MG/L	4.87
WP39	74.7

WP39 std. t.v.= 76.0 +/- 7.60

MANTECH TECHNOLOGY

MEMORANDUM

MANTECH ENVIRONMENTAL RESEARCH SERVICES CORP.
Environmental Science

In reply refer to: 99-16LP/lp
Contract # 68-C-98-138

To: Dr. Don Kampbell

Thru: D.D. Fine DDFine

From: Lynda Pennington LKP

Subject: SR # SF-0-50

Ref:

Copies: R.L. Cosby
G.B. Smith
J.L. Seeley NBL for JLS

Date: March 9, 1999

Attached are inorganic results for 26 Myrtle Beach, South Carolina, groundwater samples submitted to MERSC under Service Request # SF-0-50. The samples were received February 24, 1999 and were analyzed February 26, 1999. The methods used were Waters capillary electrophoresis method N-601 for chloride and sulfate and Lachat FIA methods 10-107-04-2-A for nitrate plus nitrite and 10-107-06-1-A for ammonia.

Quality control measures performed along with your samples included analysis of blanks, duplicates, spikes, known WPO samples and check standards.

If you have any questions concerning this data, please feel free to contact me.

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Center, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 580-436-8660 FAX 580-436-8501

Rec'd Feb. 24, 1999
Analyzed Feb. 26, 1999
by L. Pennington

SF-0-50
Don Kampbell
Myrtle Beach, SC

AMMONIA NITROGEN

Sample	Chloride (mg/L)	Sulfate (mg/L)	NO2+NO3(N) (mg/L)	Ammonia (mg/L)
2/18 MW-1	9.00	23.7	0.12	<.10
2/18 MW-2	12.5	13.2	(<.10) (<.10)	(<.10) (<.10)
2/18 MW-3	(6.36) (6.27)	(1.73) (1.73)	<.10	1.14
2/18 MW-4	14.4	3.96	<.10	0.10
2/19 MW-06	9.00	<.50	<.10	<.10
2/19 MW-07	9.85	27.0	0.19	<.10
2/19 MW-08	6.25	27.4	0.40	<.10
2/19 MW-09	7.69	23.8	0.11	<.10
2/19 MW-11	21.5	14.4	(<.10) (<.10)	(1.35) (1.35)
2/18 MP-10	7.18	2.55	<.10	<.10
2/20 MP-12D	25.5	<.50	<.10	0.26
2/19 MP-19D	38.3	<.50	<.10	0.18
2/18 MP-30D	12.0	<.50	<.10	0.22
2/18 MP-31D	22.5	<.50	<.10	0.55
2/18 MP-32D	(24.4) (24.3)	(2.06) (2.13)	<.10	0.22
2/20 MP-34D	17.2	10.8	<.10	<.10
2/20 MP-35D	27.6	3.67	<.10	<.10
2/19 MP-36D	41.4	<.50	(<.10) (<.10)	(<.10) (<.10)
2/20 MP-8S	14.9	<.50	<.10	<.10
2/20 MP-16S	5.03	2.92	<.10	<.10
2/19 MP-17S	9.54	7.86	<.10	<.10
2/19 MP-19S	10.0	<.50	<.10	<.10
2/19 MP-22S	(4.59) (4.52)	(2.82) (2.61)	<.10	<.10
2/18 MP-30S	4.67	<.50	<.10	<.10
2/20 MP-34S	23.2	33.0	<.10	<.10
2/19 MP-36S	7.85	4.79	<.10	<.10
Blank	<.50	<.50	<.10	<.10
WPO	10.7, 10.5	58.6 , 58.1	12.5	5.04
WPO T.V.	10.8	58.0	12.0	4.80
Check Standard	4.83 , 24.8	4.66 , 24.6	4.94	5.15
Chk. Std. T.V.	5.00 , 25.0	5.00 , 25.0	5.00	5.00
Spike Recovery	101%, 97%	102% , 97%	104%	103%

Myrtle Beach AFB - POL Area Site - February 1999

Sample	Temp. °C	pH	Cond. µS/cm	D.O. mg/L	Redox mV		TOC Water Table, FT
MW-01	17.1	6.2	251	1.8	+132		4.7
MW-02	17.8	5.4	152	0.2	-129		8.0
MW-03	17.0	6.2	223	0.0	-170		7.1
MW-04	19.7	6.1	303	0.1	-148		8.4
MP-31D	20.3	7.0	488	0.6	-115		7.6
MW-05	Lost data sheet						
MP-32D	20.1	7.1	462	0.2	-101		6.2
MP-30D	19.1	6.9	490	0.2	-155		6.7
MP-30S	16.3	6.2	393	0.2	-130		6.6
MP-10S	16.8	6.5	240	3.2	-1		2.3
MP-19D	18.8	7.2	530	0.1	-12		
MP-19M	Very low yield well - Took BTEX only						7.9
MP-19S	Very low yield						8.7
MP-36D	17.9	7.2	410	0.0	-42		5.1
MP-36S	15.1	5.7	58	1.0	-5		4.8
MP-22S	16.5	5.6	44	0.3	-29		4.3
MW-07	17.8	5.1	128	0.6	+90		7.8
MW-11	18.3	6.2	340	0.4	-21		10.7
MW-06	18.1	6.0	176	0.9	-60		10.7
MP-18M	Very low yield - Took BTEX only						8.2
MP-17S	18.2	5.7	150	0.4	+114		7.1
MW-08	17.9	5.0	118	0.2	+143		8.2
MW-09	16.5	6.7	670	2.5	+141		6.3
MP-12D	18.8	7.1	514	0.1	+1		5.7
MP-16S	16.8	5.8	70	0.9	+66		4.5
MP-8S	15.9	6.1	175	0.7	+42	Low yield well	4.6
MP-35D	18.8	7.3	497	0.1	-6		4.4
MP-34D	18.3	7.2	458	0.4	-25		3.5
MP-34S	17.5	6.8	1100	0.3	+5		3.5

Myrtle Beach AFB – POL Area Site – February 1999

Sample	Ferrous Iron mg/L	Alkalinity mg/L	Sulfide mg/L (→ HYDROGEN SULFIDE?)	Free CO_2 mg/L
MW-01	0.2	80	<.1	80
MW-02	2.0	40	1.5	140
MW-03	37.	120	0.7	170
MW-04	2.0	140	0.7	160
MP-31D	0.8	220	<.1	45
MW-05	Lot of floating product – didn't sample			
MP-32D	0.6	180	0.1	30
MP-30D	1.2	240	0.1	55
MP-30S	20.	120	0.5	200
MP-10S	4.0	100	0.1	60
MP-19D	0.3	220	<.1	45
MP-19M	Very low yield – No sample			
MP-19S	10.	60	2.0	120
MP-36D	1.5	180	<.1	30
MP-36S	2.0	40	0.5	35
MP-22S	0.8	20	1.0	60
MW-07	3.0	10	0.2	110
MW-11	50.	100	0.5	160
MW-06	25.	60	2.0	110
MP-18M	Very low yield – didn't sample			
MP-17S	0.9	20	0.9	50
MW-08	0.3	10	0.1	90
MW-09	0.1	320	<.1	60
MP-12D	0.6	200	0.2	45
MP-16S	0.8	20	0.1	40
MP-8S	Too Turbid – Muddy			
MP-35D	0.8	220	0.1	100
MP-34D	2.0	240	<.1	20
MP-34S	20.	>2000	<.1	>200

Some chemical contaminant?

FK